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NIGHT VISION STUDIES

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(PRELIMINARY REPORT)

U.S. Army. Field Artillery School, Fort Sill, Okla.

FOREWORD

Interest in the problems of conducting military operations at night led the Field Artillery School to explore techniques for evaluating ability to see at night. In the course of this exploration, contact was made with The Adjutant General's Office and arrangements effected to provide technical assistance on certain aspects of the researches reported herein. These researches were conducted by Major Lee O. Rostenberg and his staff at the Field Artillery School, Department of Gunnery, and the report to follow has been prepared by them.

It is published by this office in order to make the findings available at once to the not inconsiderable body of research and operational personnel concerned with these problems. It is recognized that the results reported are not entirely conclusive, because of the limited sample on which validation data were obtained. This limitation resulted from circumstances which it was not possible to control. Additional validation data have now been secured and are in process of analysis. A further report covering the later study, carried out by this office at the Infantry Training Center, Camp Blanding, will be published at the earliest practicable date.

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TABLE OF CONTENTS

408631

LIST OF EXHIBITS

DEPARTMENT OF GUNNERY
FIELD ARTILLERY SCHOOL
FORT SILL, OKLAHOMA

17 February 1944

SUMMARY

1. REPORT OF.— Night Vision Study

2. GENERAL CONCLUSIONS.—

a. With much of modern warfare waged at night, it is essential that all existing means be employed whereby the night vision of troops and their ability to observe are improved. This may be attained by:

(1) Selection of personnel for night operational duties on the basis of their night vision ability - assigning men with superior night vision to vital night duties, and those with poorest night vision to least important night duties.

(2) Systematic education and training of all personnel in the efficient use of the eyes at night. Efficient night vision is a matter of indoctrination and training as well as of inherent ability.

(3) Provision of all possible aids to night vision, such as proper red light in lighting devices, night glasses, dark-adaptation goggles, and scrupulous cleanliness of glass surfaces.

b. The British, the Russians, the U.S. Navy, and the Army Air Forces have all benefited by programs of night vision training similar to that presented in the foregoing paragraph and are continuing strenuous efforts to improve their tests, training methods, and aids. It is logical to assume that the Field Artillery will benefit similarly.

c. The Field Artillery School Mass Night Vision Test, described in this report as NVT and specified in detail in Appendix II, seems to be the best test available at this time for classification of personnel in the field according to their night vision abilities. Of all known tests, it most closely fulfills these requirements:

(1) It is simple and within the resources of the average field unit.

(2) It is reliable; that is, men score the same or nearly the same when tested a second or third time.

(3) It has validity; that is, gives results that directly grade and represent a man's ability to see at night under usual field conditions.

(4) It permits testing of a large number of troops within a short time.

(5) It is standardized or capable of standardization for use throughout the Field Artillery (or other Arms).

(6) It requires minimum personnel to supervise, administer, and evaluate the tests.

No test has been available hitherto which meets these requirements. The optional test mentioned in Training Circular 44, 1942 is crude and of dubious value.

d. As to desirability for immediate use by units in the field, the NVT 15 is best suited as a design for troops themselves to build. It is relatively fool-proof. However, the factors involved in night vision are complex. Also, field units notoriously dislike building items themselves. Hence, it would be safer and generally more satisfactory if the Night Vision Tester is built at a central point and distributed to units. In such case, the radium-activated or film-strip type NVT is to be preferred.

e. Although the validity coefficients for the best tests developed are much higher than any previously recorded, the cases are too few for final conclusion. Hence, further validation work should be done along the same or similar lines with a larger control group.

f. In the light of most recent information available, Section IV, WD Training Circular No. 44, July 1942 is in considerable part obsolete and should be rescinded or materially rewritten. It should be supplemented with training films, film strips, and suitable charts.

g. A Night Combat Board seems urgently needed to investigate and be responsible for all the problems relating to night combat, and to develop the most efficient tactics, techniques, and instruments for all the Arms for night operations. It could serve to coordinate and utilize present, disconnected efforts.

3. RECOMMENDATIONS.-- It is recommended that

a. The Field Artillery School Mass Night Vision Tester, Model NVT 15 be approved for immediate use in the field, and that instructions for its construction and use be disseminated to all units.

b. The first recommendation above be considered as a necessary, temporary expedient and as soon as possible a standard NVT-model Night Vision Tester, preferably of the radium-activated or film-strip type, be procured and supplied to units through normal channels.

c. Unit commanders be directed to test their personnel for abilities to see at night and to utilize the classifications obtained as a guide for judicious assignments to night duties.

d. A comprehensive program for night vision training of troops be prepared and incorporated with the training programs of replacement centers and field units. This should include not only preselection of personnel, but also

(1) Orientation, indoctrination, and instruction in proper night vision techniques and aids.

(2) Wide employment of suitable training films, film strips, and charts.

(3) Exercises in recognition of objects at night.

(4) Integration of night vision training with other tactical and technical training conducted at night.

e. Units be furnished with the necessary instructional and training materials to carry out the recommended training program.

f. Night vision research and development be continued elsewhere with adequate staff and facilities to

(1) Obtain further validation and reliability data on the Field Artillery School Night Vision Tester in its various forms.

(2) Study and evaluate other adaptometers or testers developed by the Army Air Forces, U.S. Navy, and others.

(3) Determine means and methods of further improving night vision techniques and aids.

g. There be authorized and formed a Night Combat Board to investigate and have responsibility for all the problems relating to night combat, and to coordinate present researches pertaining thereto. This Board is to have representation from all the Arms and Services.

17 February 1944

REPORT OF NIGHT VISION STUDY

1. PURPOSE.—

a. To determine the most efficient means whereby commanders of Field Artillery units in the field may classify their personnel according to their relative abilities to see at night so that appropriate duty assignments can be made for night operations and night combat.

b. To present the procedure in a final form suitable for publication as a Training Circular if so desired by War Department or Army Ground Forces.

2. AUTHORITY.— Directive of the Commandant, Field Artillery School, 15 July 1943, and his subsequent further instructions.

3. PERIOD OF STUDY.— 24 August 1943 to 10 February 1944.

4. NECESSITY FOR STUDY.—

a. With much of modern warfare waged at night, and operations usually conducted under total black-out conditions, it is obvious that inefficiency, and at times disaster, can and does result when soldiers who are night blind, or who have poor night vision, are trained and employed for duties where good or superior night vision is essential.

b. Field Artillery observers and others in and from combat zones have reported repeatedly and definitely that it is most necessary that proper attention be given to this important subject of night vision.

c. That this problem was recognized early by the War Department is shown by its publication of Training Circular No. 44, 24 July 1942, which states that "for night operations it is essential that troops be trained to avail themselves of all existing means whereby night vision and the ability to observe are improved." It also states "unit commanders will identify those individuals within their units who possess decreased ability to adapt to darkness...." This circular describes a crude test which, however, is of dubious value. In the light of recent information available from studies here and elsewhere, much of Section IV, WD Training Circular No. 44, 24 July 1942, is obsolete or inadequate.

d. Wide and careful survey disclosed that no satisfactory night vision test or test device was available for field troops. Outdoor tests are practically useless, since night illumination varies so considerably and since there are so many other uncontrollable and distracting factors.

e. Reliance could not be placed on studies made elsewhere, such as in the Army Air Forces, the Navy, and the Armored Forces, mainly because their problems and approaches were materially different from those of the Field Artillery and other Ground Forces.

5. DISCUSSION OF NIGHT VISION.—

a. The more elementary facts of night vision are explained in a paper "Night Observation" appended hereto as Appendix I. It can be stated, however, that night

vision is distinctly different from day vision and involves a different set of cells and a different section of the retina than day vision. A person may see excellently in the daytime and poorly at night, and conversely. A rough borderline between day vision and night vision is bright moonlight, although there is a relatively narrow range where both are operative.

b. The factors involved in night vision are highly complex; many are still relatively unknown and unexplored. All visual judgments are complicated, and many factors enter into the simplest visual perception. In no instance does the performance of a visual task depend solely on illumination or any other single factor.

c. Night vision itself is not a simple unit of performance or a single ability but may be considered as a combination of aptitude and training. The two most important methods of measuring it are rate of dark adaptation (important in reaction to glare, gun flashes, etc.) and the ultimate maximum level of dark adaptation attainable. The latter is probably the largest practical factor in night vision, although visual acuity and contrast sensitivity probably are other important factors.

d. Night vision, it has been found, is a constantly fluctuating ability, both quantitatively and qualitatively. The human being involved is affected by many physical and mental factors that in turn affect the mechanisms of night vision both physiologically and psychologically.

e. Accurate laboratory and instrument reproduction of the extremely low light values and of other complex physical conditions found at night poses many practical difficulties. No reliable and valid test for night vision has yet been devised which does not require blacked-out conditions for testing.

6. DESIRED CHARACTERISTICS.— It was decided that a night vision test and test procedure for Field Artillery personnel should fulfill the following requirements:

a. It should be simple and within the resources of the average field unit and must have a minimum learning factor.

b. The test should be reliable, that is, men should score the same or nearly the same when tested a second or third time.

c. It should have validity, that is, give results that directly grade and represent a man's ability to see at night under usual field conditions.

d. It should permit testing of a large number of troops within a short time.

e. It should be standardized or capable of standardization for use throughout the Field Artillery.

f. It should require minimum personnel to supervise, give, and evaluate the tests.

7. METHOD OF INVESTIGATION.—

a. A suitable laboratory was made available, a research staff was selected and trained from locally available instructors, and a "pilot" experimental night vision tester (hereafter called NVX Model) was designed and built from locally available materials. It is illustrated in Exhibits A-1 and A-2. Because the Army Air Forces-Eastman Night Vision Tester seemed to be the most advanced of all test devices studied, its light levels and test character were used initially in the NVX. However, the mechanical designs were radically different. Pain-

OBLIQUE VIEW OF NVX VIEWER SHOWING ROTATING HEAD
AND AIRPLANE CHARACTER

EXHIBIT A-1

INTERIOR VIEW OF NVX VIEWER, TOP OPEN

(Interior Dimensions 20"x20"x38")

EXHIBIT A-2

staking calibration indicated that the brightness levels of the NVX were of the accuracy stipulated for the $3,000 Army Air Forces-Eastman instrument.

b. Using this initial NVX model as a standard and as a point of departure, different and varied tests and test devices were developed, ultimately resulting in a satisfactory, simple field Night Vision Tester.

c. An experimental group, consisting of members of a representative Field Artillery battery, initially 107 men and officers, was used throughout the investigation for both the laboratory and field tests. This group was given all the different tests for validity and reliability purposes. Parallel testing of the experimental group was done with the Feldman Adaptometer and the Luckiesh-Moss Low Contrast Chart with varying conditions of time and illumination. Results on these tests follow herein.

d. Initially, a number of gunnery instructors and a group of Negro soldiers were tested on the devices first developed, to determine the best methods and procedures for subsequent testing. This was necessary to avoid the possibility of destroying the value of the tests for use with experimental personnel.

e. Other school troops were given both laboratory and field tests from time to time on a voluntary basis. Valuable reliability data and some validity data were obtained from these.

f. Outdoor tests were given, some to check more conclusively the TC 44 test and its possible use in modified form, the others to be developed and utilized as criteria for the indoor tests.

g. At all times, the study was conducted under controlled conditions and by the best scientific methods possible. Results were continuously evaluated statistically and objectively, and lessons learned or indicated were utilized in following experiments.

8. THEORETICAL BASIS FOR DESIGN USED.--

a. In developing and standardizing a test for determining the ability of military personnel and others to see under the low brightness levels of night, it is logical to assume that the ocular examination should be conducted with brightnesses that are photometrically comparable to those encountered in observation. This premise has been followed in this study.

b. Night illumination varies from full moonlight to dimmest starlight. What we see is the reflected light from the night sky on roads, trees, grass, rocks, water, and other objects. Perception is based on the contrast between the various objects and their backgrounds, either light against dark or dark against light. Individuals who can see well at comparatively high levels of night brightness may "blank out" at increasingly lower levels. Accordingly, the test was designed to duplicate photometrically various representative stages of light brightnesses and contrasts generally found at night. The range selected was from half moonlight reflected from a concrete road to starlight reflected from trees.

c. Night vision under black-out conditions is "off-center" vision, and the eyes' powers of discrimination of detail are much poorer than in day vision. Therefore, objects to be seen and recognized must be relatively large with respect to their backgrounds. Much less visual acuity is required than in day vision. A test character of proper size and visual acuity load had to be determined for the

light levels used. This test character, means to change its position, and the screen on which the various light levels were to be shown had to be incorporated into a single, simple viewer.

9. NIGHT VISION STUDIES ELSEWHERE.—

a. The most significant recent night vision studies in this country seem to have been done by research sections of the Army Air Forces and the U.S. Navy. Much valuable information from these sources was obtained and utilized. The Armored Forces Medical Research Laboratory also has been investigating the problem of night vision, particularly in relation to tanks.

b. There have been a few, apparently unproductive, attempts to validate night vision tests. As yet, no report has been received of a very recent and promising validation procedure attempted at the U.S. Submarine Base, New London, Connecticut.

c. It is known that the Russians, Germans, British, and Canadians have made intensive studies of the subject of night vision. Only general information concerning the Germans and Russians is available. The British are supposed to have a good night vision tester of a laboratory type. They stress night vision indoctrination and training very highly and use a number of effective training films. The Canadians make use of a modified Hecht-Schlear Adaptometer, a laboratory instrument for individual testing.

d. A partial bibliography of published pertinent reference material is appended at the end of the report.

10. EARLIER INVESTIGATIONS.—

a. Before this study, local experience in night operations in the field indicated the need for a means of efficient preselection of personnel, such as observers, drivers, etc., for night duties. Because the optional night vision test in Section IV, WD Training Circular No. 44, 1942 was considered highly unsatisfactory, a wide search was initiated for an efficient test, or basis for a test, for night vision. Local experimental work was performed confirming the need for a better attack on the problem.

b. This wide search was made not only throughout the literature, but by correspondence and personal contact with other Army and civilian research authorities and laboratories. It was during this search that The Adjutant General's Office was contacted for information, with the subsequent collaboration, to a limited but important extent, of their Technical Section in this study.

11. PARTICIPATION OF THE ADJUTANT GENERAL'S OFFICE.—

a. The Personnel Research Subsection, Technical Section, Classification and Replacement Branch, The Adjutant General's Office, with due authorization, sent two technicians to the Field Artillery School on 16 July 1943 for short temporary duty to assist in completing plans for the study and exploring possible criterion measures. Since then, this section has rendered valuable aid in obtaining and furnishing reports on night vision investigations elsewhere, and in checking and analyzing locally collected data.

b. By War Department letter orders, 10 December 1943, an officer was ordered to temporary duty with the aforementioned office in New York and Washington, D. C.

from 1 to 22 December 1943. Field data of the studies were taken as ordered, and these were thoroughly evaluated by the Personnel Research Subsection with the assistance of the officer.

c. This duty also made available:

(1) Laboratory facilities for solving certain technical problems not available at Fort Sill.

(2) Information and data from certain research sections of the Army Air Forces, Navy, National Defense Research Committee, the Engineer Board, and other agencies concerned with night vision.

d. Detailed report of this temporary duty was submitted to the Commandant on 15 January 1944.

12. FACILITIES AND PERSONNEL.—

a. An excellent dark room and a laboratory were made available through alteration of an existing standard A-7 type, temporary building. Alteration is shown in Exhibit B.

b. The amount of scientific and other equipment was severely limited.

(1) The only commercially built items available for use were a Taylor Model "A" Low Brightness Meter, Exhibits C-1 and C-2, previously purchased from the General Electric Company and a Feldman Adaptometer, loaned by Dr. Feldman.

(2) Other tools and equipment were devised, built, or borrowed locally, except for very minor miscellaneous purchases. Electrical items, tools, automotive parts, etc. used were government issue.

c. The Luckiesh-Moss Low Contrast Test Chart was available.

d. The Research Staff consisted of nine instructors of the department of gunnery. Of these, three had varied scientific and research experience, two were engineers with tool-design experience in civilian life, and one of the staff was an experienced statistician. In the outdoor validation tests, the staff was augmented as needed by additional gunnery instructors who were specially trained in their specific tasks.

13. LABORATORY TESTS, GENERAL.--

a. Several existing test devices were investigated concurrently with the detailed studies using first the pilot model, experimental tester NVX, and later using the other tests developed.

b. These test devices are as follows:

(1) NVX - First Experimental Laboratory Model (Exhibits A-1 and A-2).

(2) NVT - Experimental Field Model (Exhibits D-1, D-2, and D-3).

(3) NVT PB - Experimental Field Model made from QM clothing packing box (Exhibits E-1 and E-2).

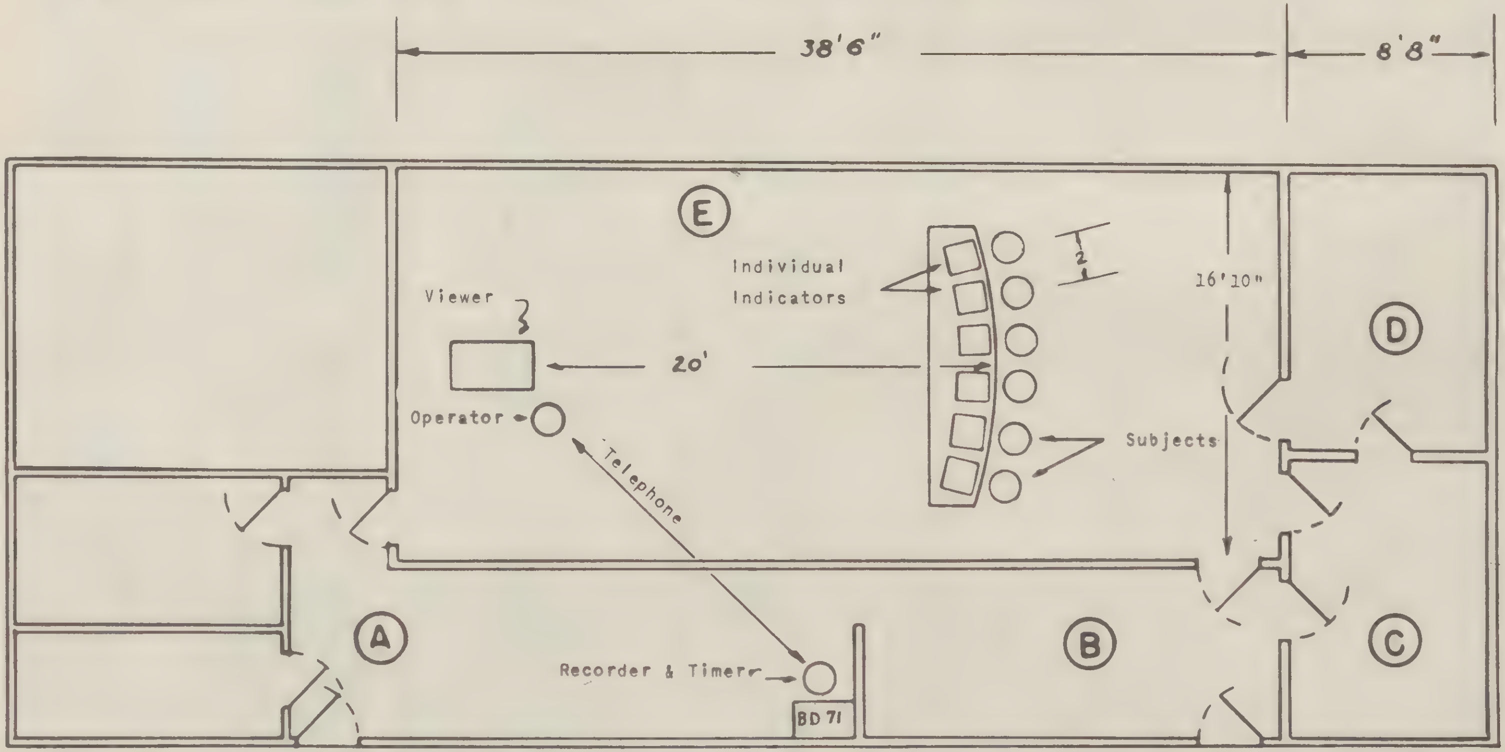
* pp. 6-7

A - OFFICE

B - ORIENTATION & PREADAPTATION ROOM

C & D - DARK ADAPTATION ROOMS: LIGHT TIGHT

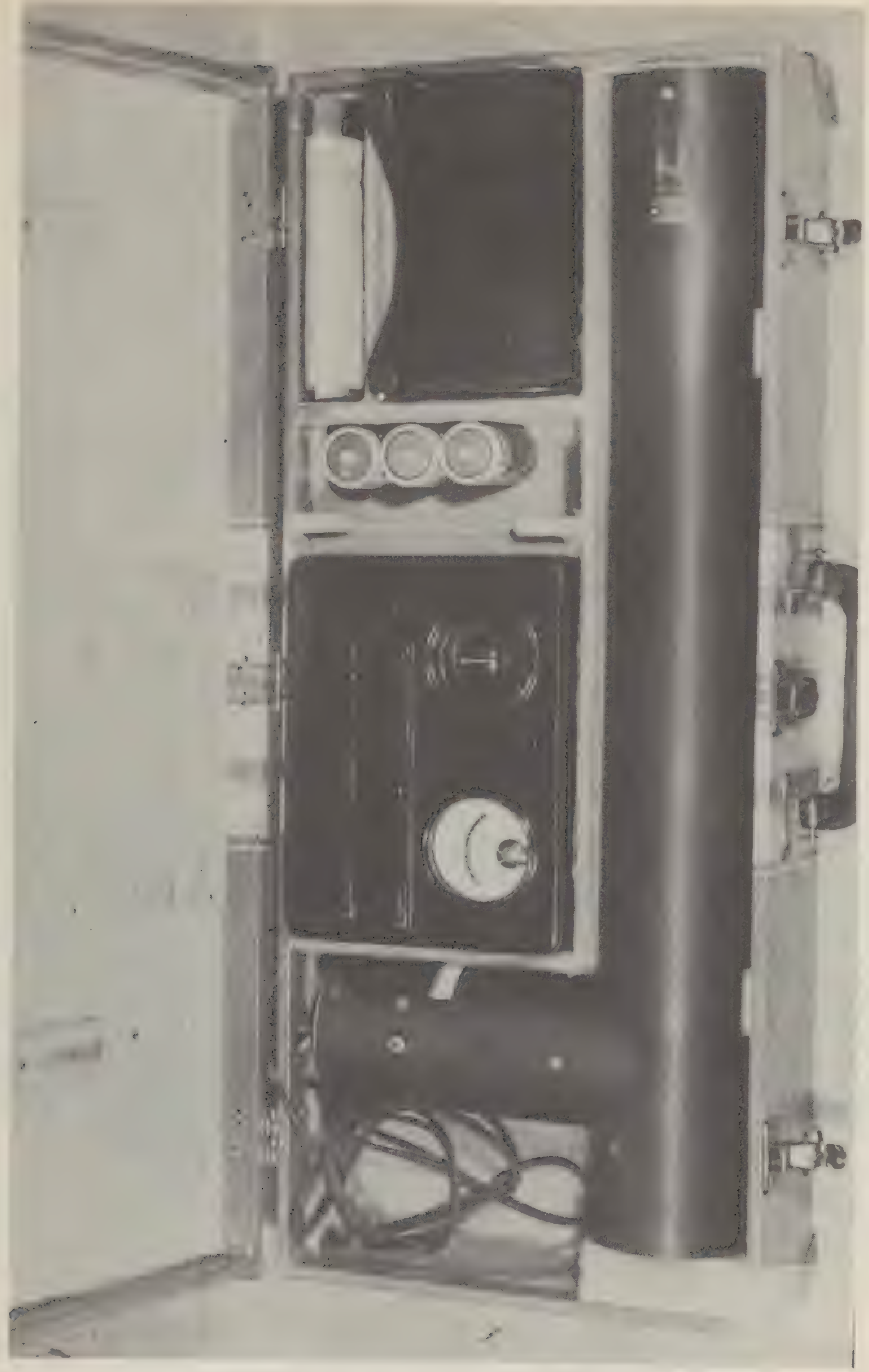
E - TEST ROOM: LIGHT TIGHT



FLOOR PLAN OF BUILDING T-438
N V LABORATORY
AFTER ALTERATION

SCALE: 1/8" = 1'

EXHIBIT B



TAYLOR LOW BRIGHTNESS METER (MODEL A)

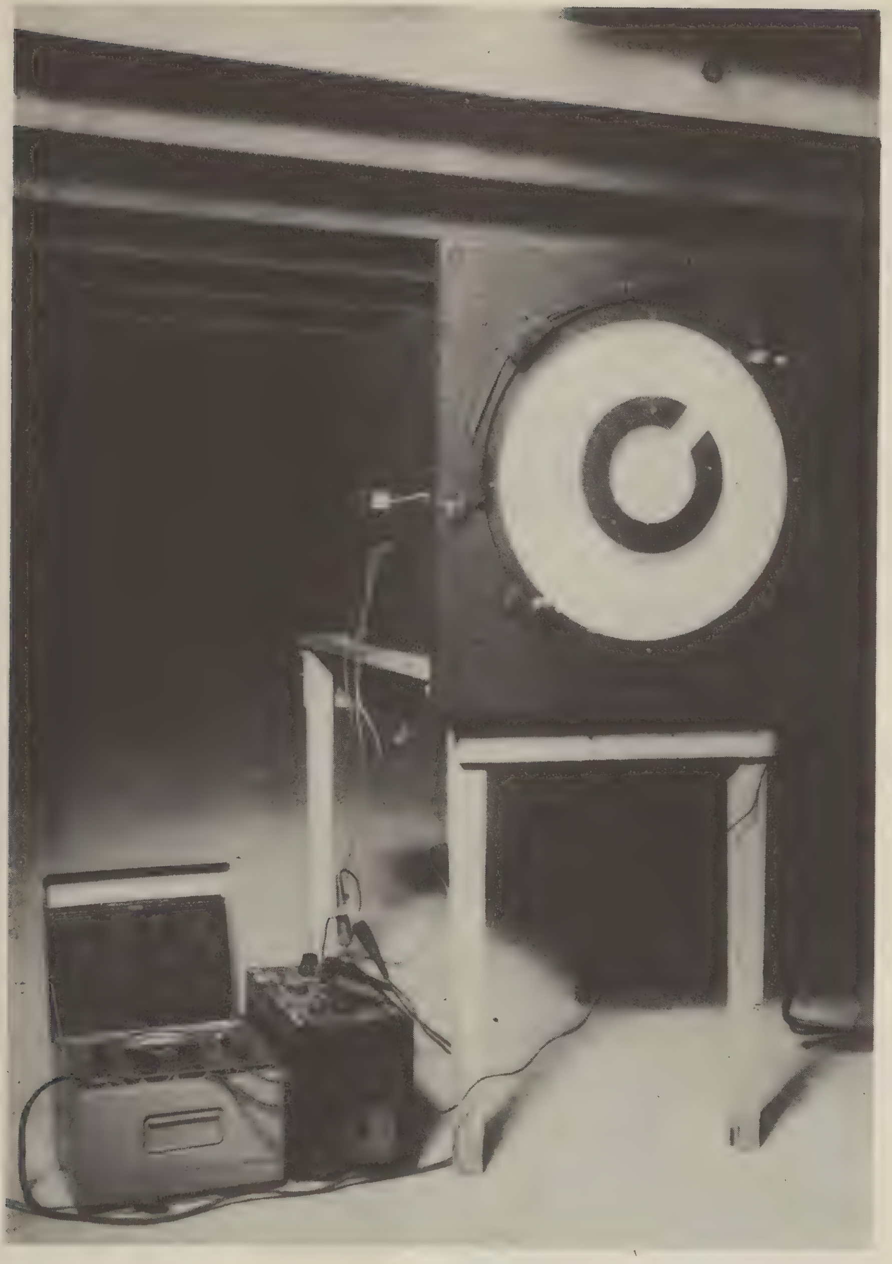
With Carrying Case

EXHIBIT C-1

TAYLOR LOW BRIGHTNESS METER (MODEL A)

Showing Meter In Use

EXHIBIT C-2



OBLIQUE VIEW OF NVT VIEWER SHOWING ROTATING HEAD, 2° LANDOLT RING TEST FIGURE, 6-VOLT STORAGE BATTERY AND THE LOW-VOLTAGE CIRCUIT TESTER

EXHIBIT D-1

LOW-VOLTAGE CIRCUIT TESTER

(USED WITH NVT MODELS TO MAINTAIN DESIRED VOLTAGE)

EXHIBIT D-2

INTERIOR VIEW OF NVT VIEWER

(TOP REMOVED)

EXHIBIT D-3

OBLIQUE VIEW OF NVT PB VIEWER

(This Viewer was made from a Salvaged

Quartermaster Clothing Packing Box)

EXHIBIT E-1

INTERIOR VIEW OF NVT PB (WITH FRONT REMOVED)

Showing Circular Disc With Graded Holes

EXHIBIT E-2

(4) NVT FS - Experimental Model using a Projector and Film Strip (Exhibits F-1, F-2, and F-3).

(5) NVT R1 and NVT R2 - Experimental Models using self-illuminous radium-activated light sources. (Exhibits G-1, G-2, G-3, G-4, and G-5).

(6) Feldman Adaptometer (Exhibits H-1, H-2, and H-3).

(7) Luckiesh-Moss Test Chart (Exhibit I).

c. Each experimental field model was designed to be as simple as possible and within the capabilities and limited facilities of field units.

d. Mass Testing Equipment.— Group testing takes less time than individual testing. Since it is necessary to conduct night vision tests under black-out conditions, any mass testing involving oral responses on the parts of the subjects would be confusing. Two simple means of recording were evolved. One utilizes a BD-71 or BD-72 switchboard in conjunction with simple individual dial indicators by which individuals signal their judgments. The correct answers are scored by means of the switchboard drops. Complete description and specifications are in Appendix II, Part II. Indicator units are shown in Exhibit J. The other method involves the use of a special pad and pencil (Exhibit K).

14. DESCRIPTION OF LABORATORY TESTS.—

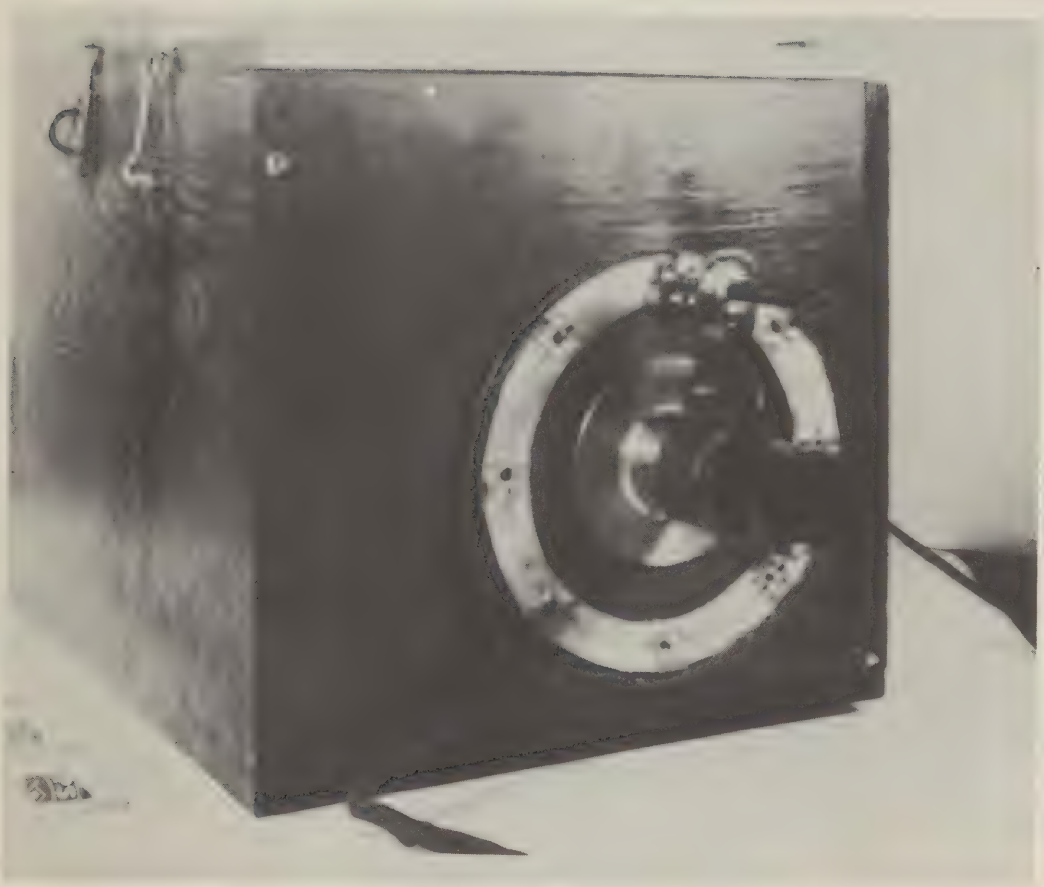
a. NVX - First experimental model night vision tester (Exhibits A-1 and A-2)*. This is essentially a light-diffusion box which utilizes a rather complex system to obtain evenly diffused light through an opal glass screen against which was exhibited a black opaque test character.

In some experimental studies, a trans-illuminated test character was used against an opaque background. The light source was a well-seasoned 50-watt, 32-volt light bulb burned at 13 volts by means of a transformer. The current was obtained from an exceptionally steady 110-120 volt A.C. supply. A specially constructed and well calibrated tapped resistance coil was used to produce the 8 successively lower brightness levels used in nearly all NVX tests. A spectral filter (blue-violet) was employed.

b. NVT - Tentative field model, greatly simplified from NVX; diffused screen brightness obtained by different design for light reflection. The basic NVT viewer (Exhibits D-1 and D-3)* derives its light from three 3-candlepower 6-8-volt single-pole automobile light bulbs of standard issue, with current obtained from ordinary 6-volt storage batteries. The lamp bulbs were burned at 3.5 volts, the current being regulated through the voltmeter and the resistance of the 6000-mile motor-maintenance low-voltage circuit tester regularly issued to Field Artillery battalions (Exhibit D-2)*. The desired decreasing levels of brightnesses are obtained through graded apertures in the slide of a section of a salvaged graphical firing table. The basic model can be manufactured from items available in the field, in accordance with plans and specifications in Appendix II, Part I.

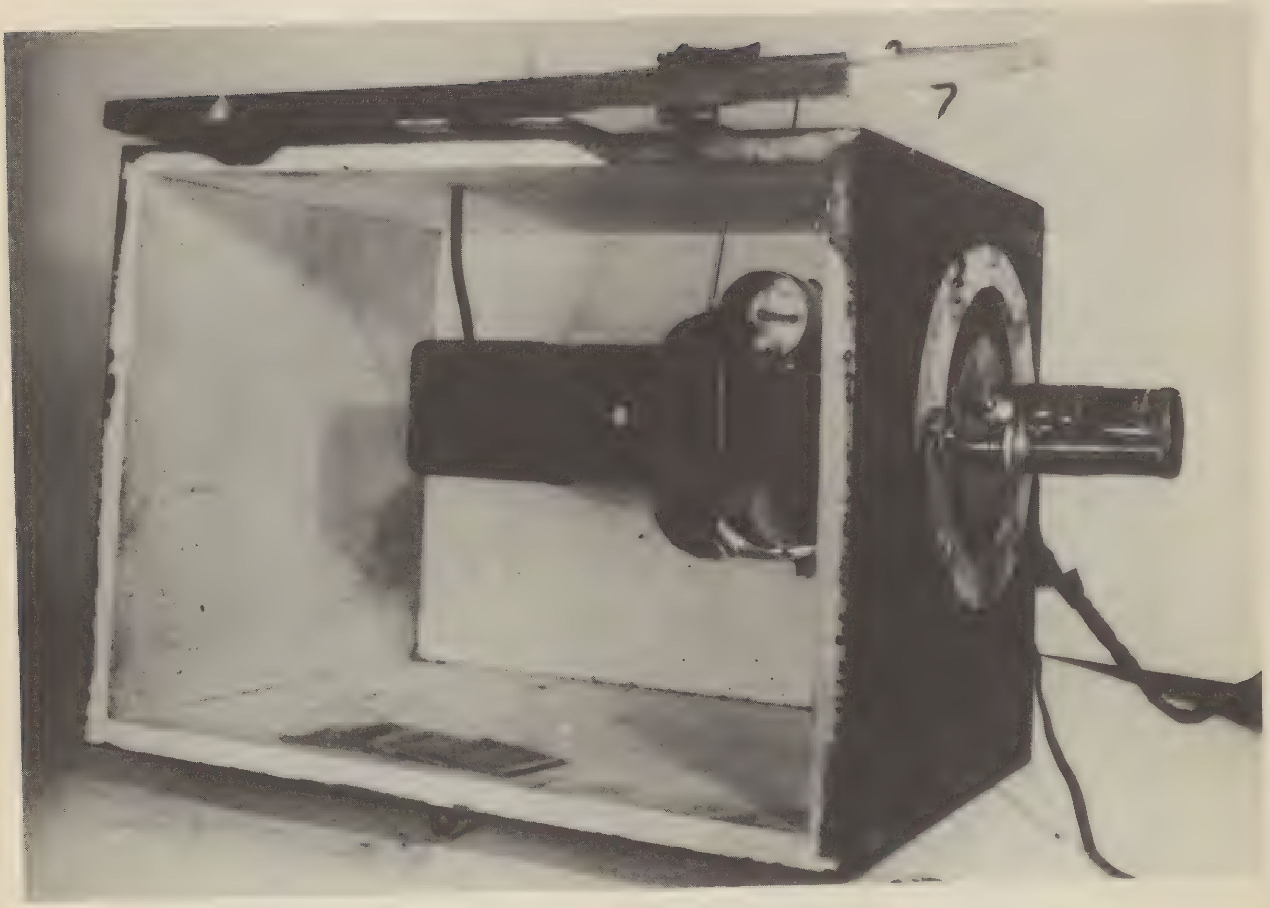
c. NVT PB - Experimental model made from QM packing box. This is shown in Exhibits E-1 and E-.*. General features follow those of the basic NVT.

* Exhibit A-1, p. 6; A-2, p. 7; D-1, p. 14; D-3, p. 16; D-2, p. 15; E-1, p. 17; E-2, p. 18.



OBLIQUE VIEW OF NVT FS PROJECTOR SHOWING FILM SLIDES AND ROTATING HEAD ADAPTED TO PROJECTOR

EXHIBIT F-1

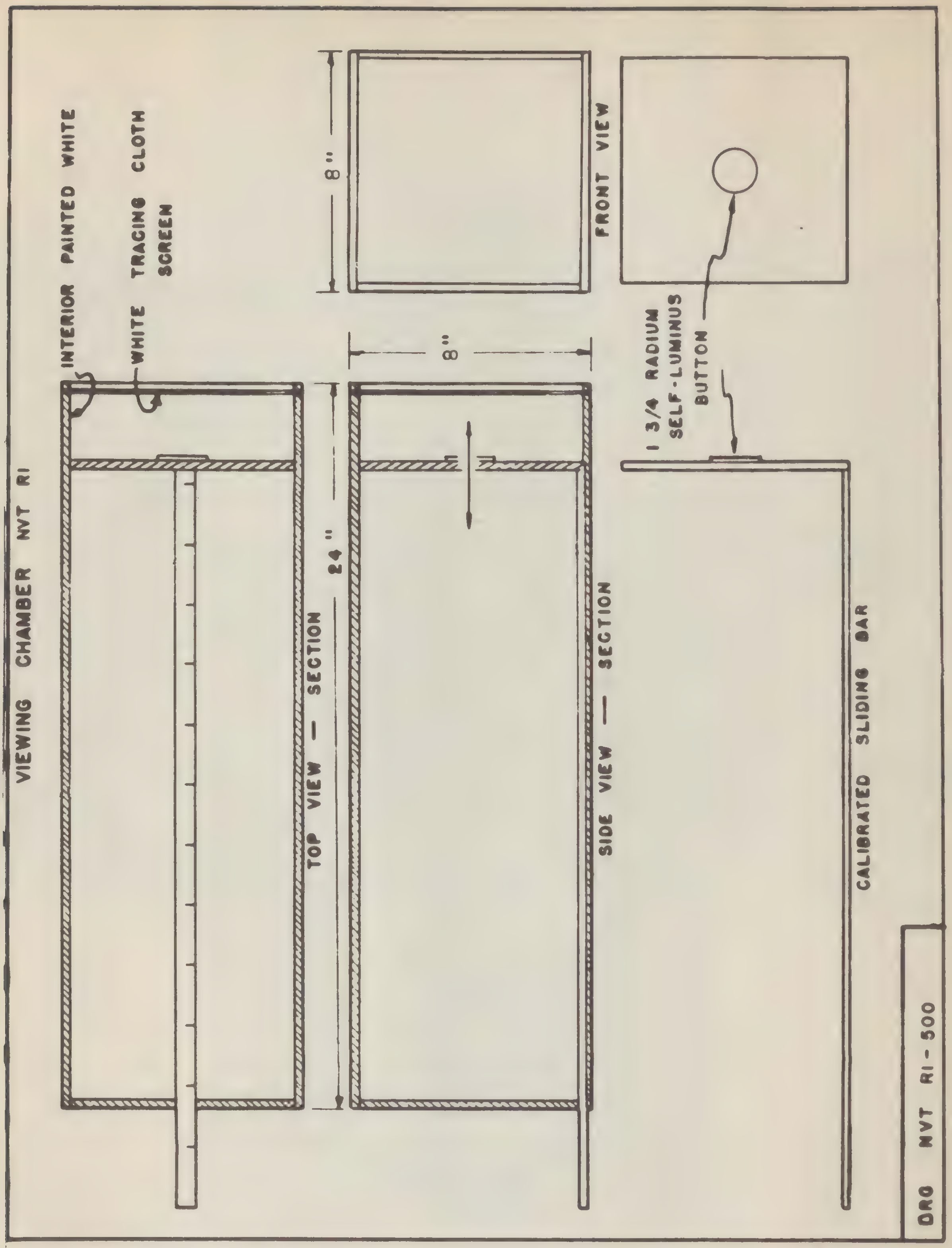


INTERIOR VIEW OF NVT FS PROJECTOR BOX

EXHIBIT F-2

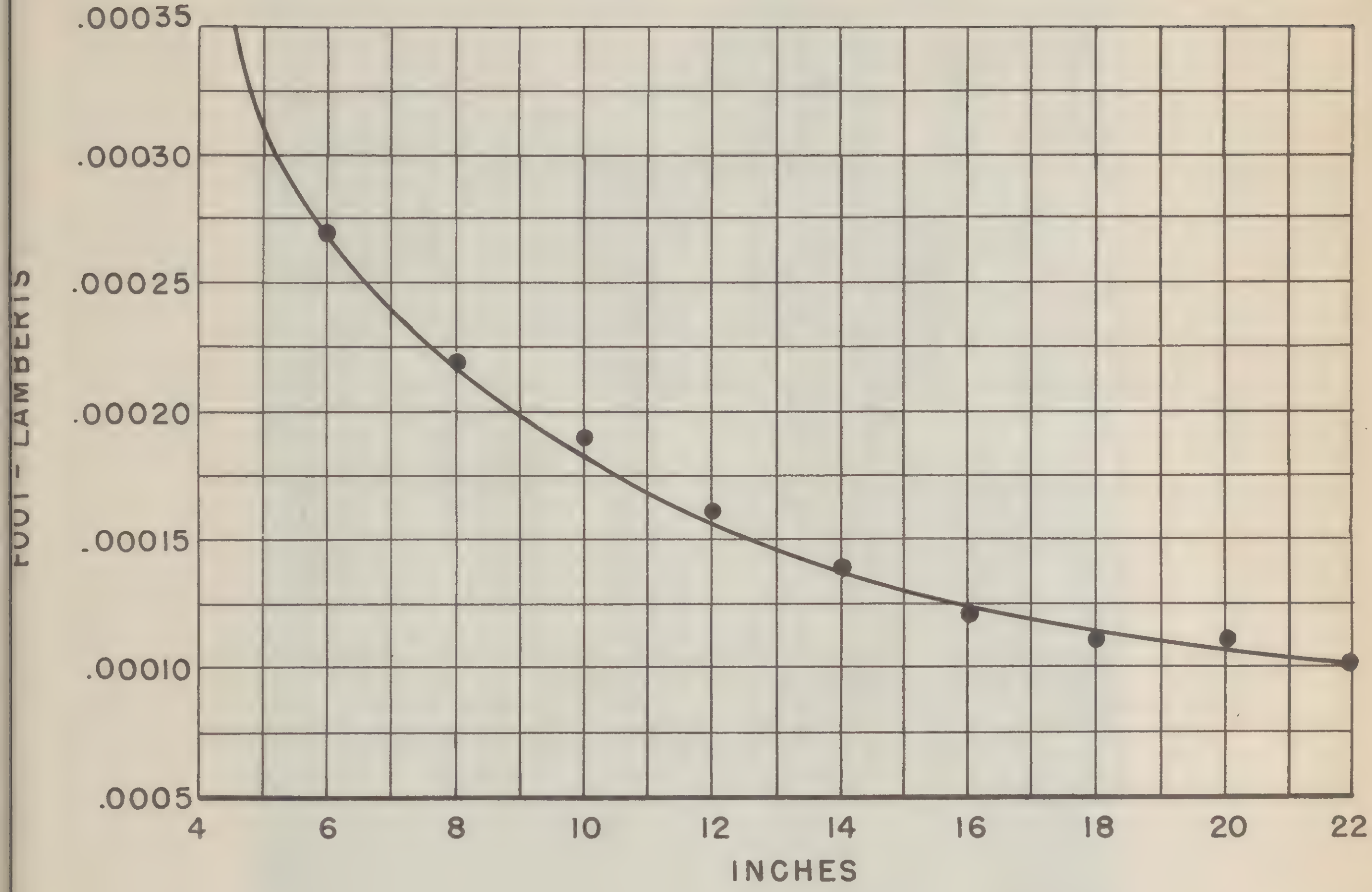
VIEW OF ADAPTER AND 3-CANDLEPOWER BULB
AS USED IN NVT FS MODEL

EXHIBIT F-3



DRAWING OF NVT RI VIEWER USING (1-3/4" DIA) RADIUM-ACTIVATED BUTTON FOR A LIGHT SOURCE

EXHIBIT G-1



GRAPH OF LIGHT INTENSITY OF VIEWING SCREEN

OF MODEL NVT RI

(This shows the Light Intensity, in Foot-Lamberts, Plotted against Distance From the Viewing Screen, in inches, of Radium Button)

EXHIBIT G-2

OBLIQUE FRONT VIEW OF NVT R2 VIEWER WITH ROTATING HEAD AND AIRPLANE FIGURE

(SHOWS VERTICAL SLIDE IN RAISED POSITION AND TWO HORIZONTAL SLIDES)

EXHIBIT G-3

OBLIQUE REAR VIEW OF NVT R2 SHOWING
RADIUM PLAQUE-HOLDER ASSEMBLY AND SLIDE CHANNELS

EXHIBIT G-4

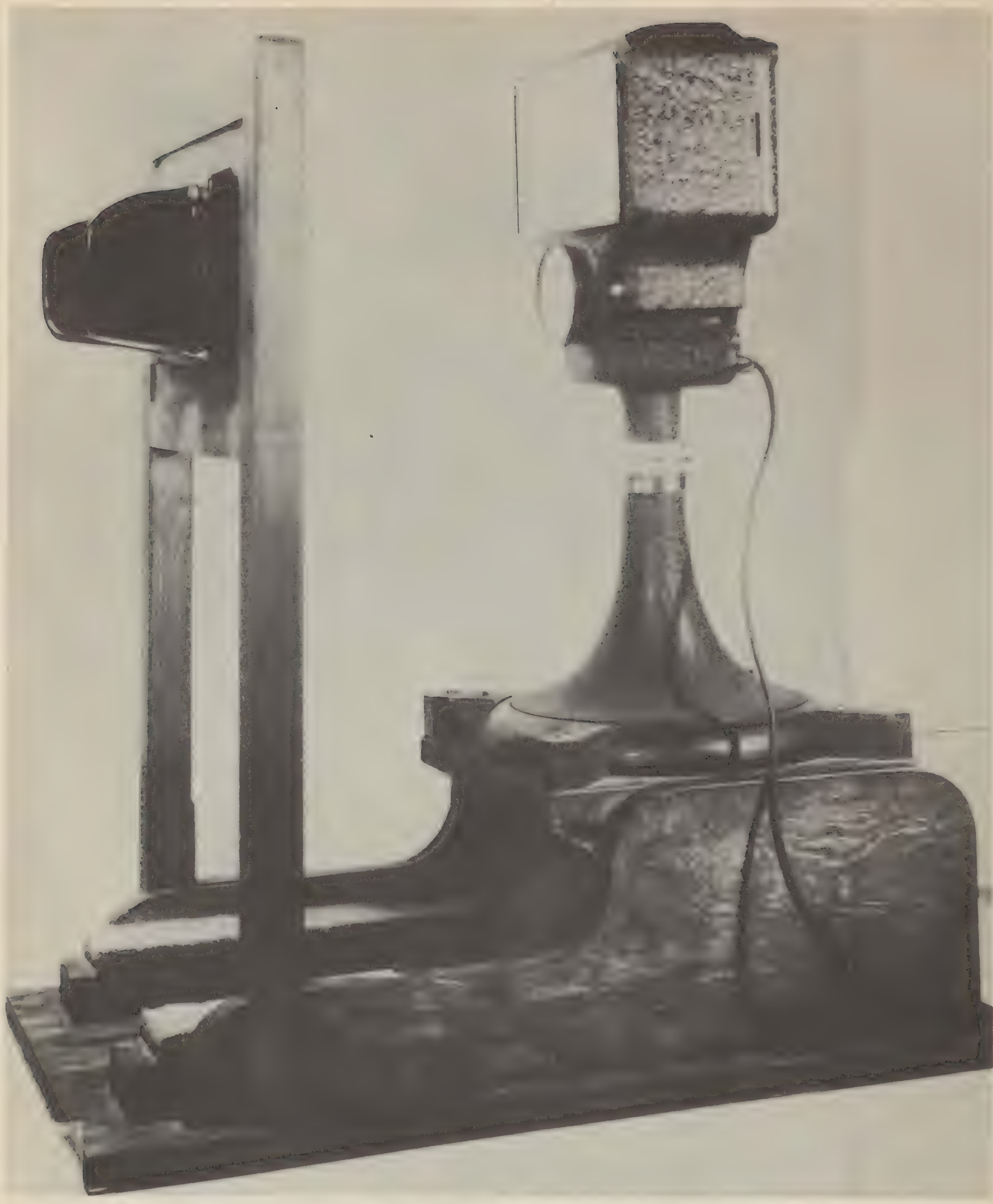
INTERIOR VIEW (FRONT REMOVED) OF NVT R2 VIEWER SHOWING A HORIZONTAL SLIDE IN POSITION COVERING A PORTION OF THE RADIUM-ACTIVATED PLAQUE

EXHIBIT G-5

OBLIQUE VIEW OF FELDMAN ADAPTOMETER
AND FAS TEST STAND

(ADAPTOMETER IN "EXPOSING" POSITION)

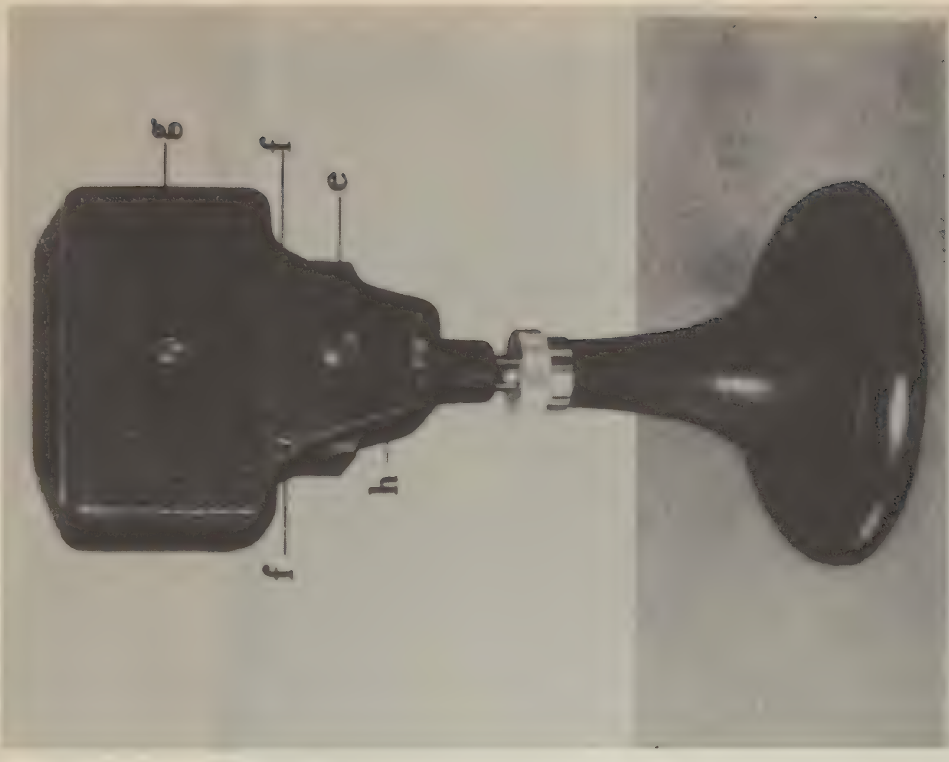
EXHIBIT H-1



FELDMAN ADAPTOMETER AND FAS TEST STAND

With Adaptometer in Test Position

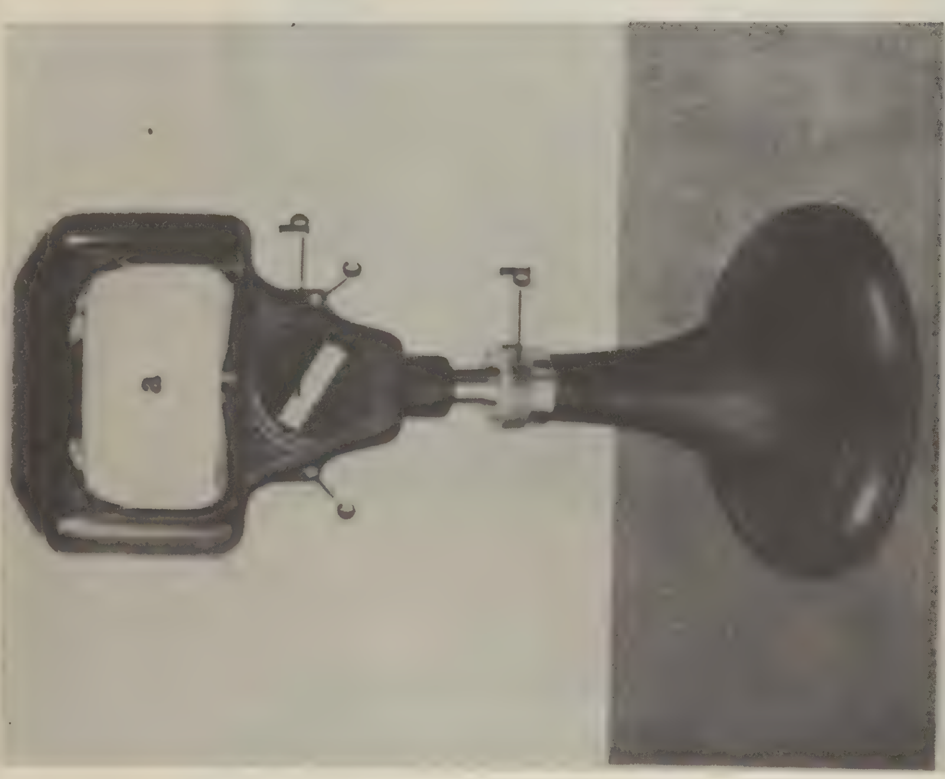
EXHIBIT H-2



Rear View (*Fig. 2*)

FIGURE 2

e. Red light to indicate that test light is on.
f. Screws for back cover.
g. Double switch [illegible]
h. Back cover.



Front View (*Fig. 1*)

FIGURE 1

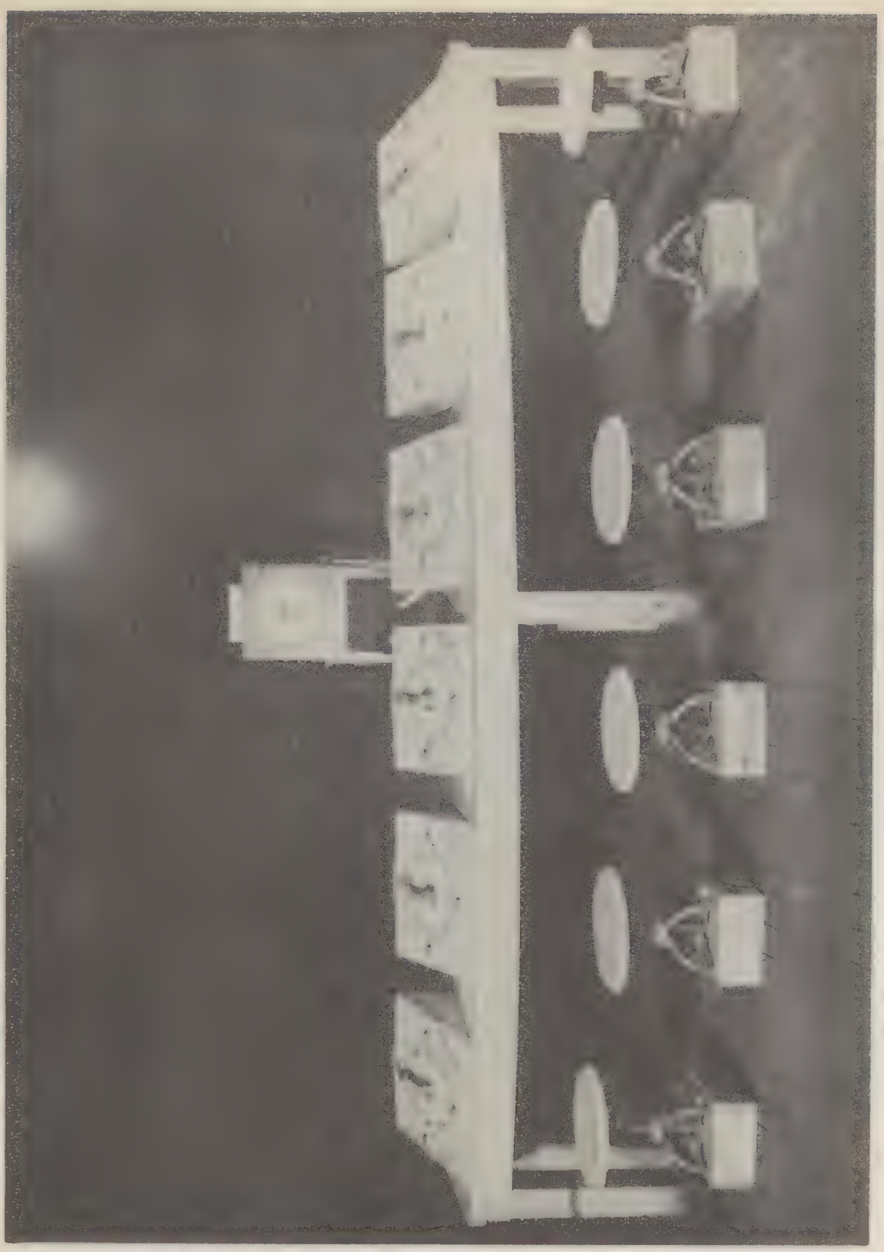
a. Pre-exposure light.
b. Rotatable stimulus or test light.
c. Protuberances for finger fixation in darkness.
d. Knurled knob for height adjustment.

FELDMAN ADAPTOMETER

EXHIBIT H-3

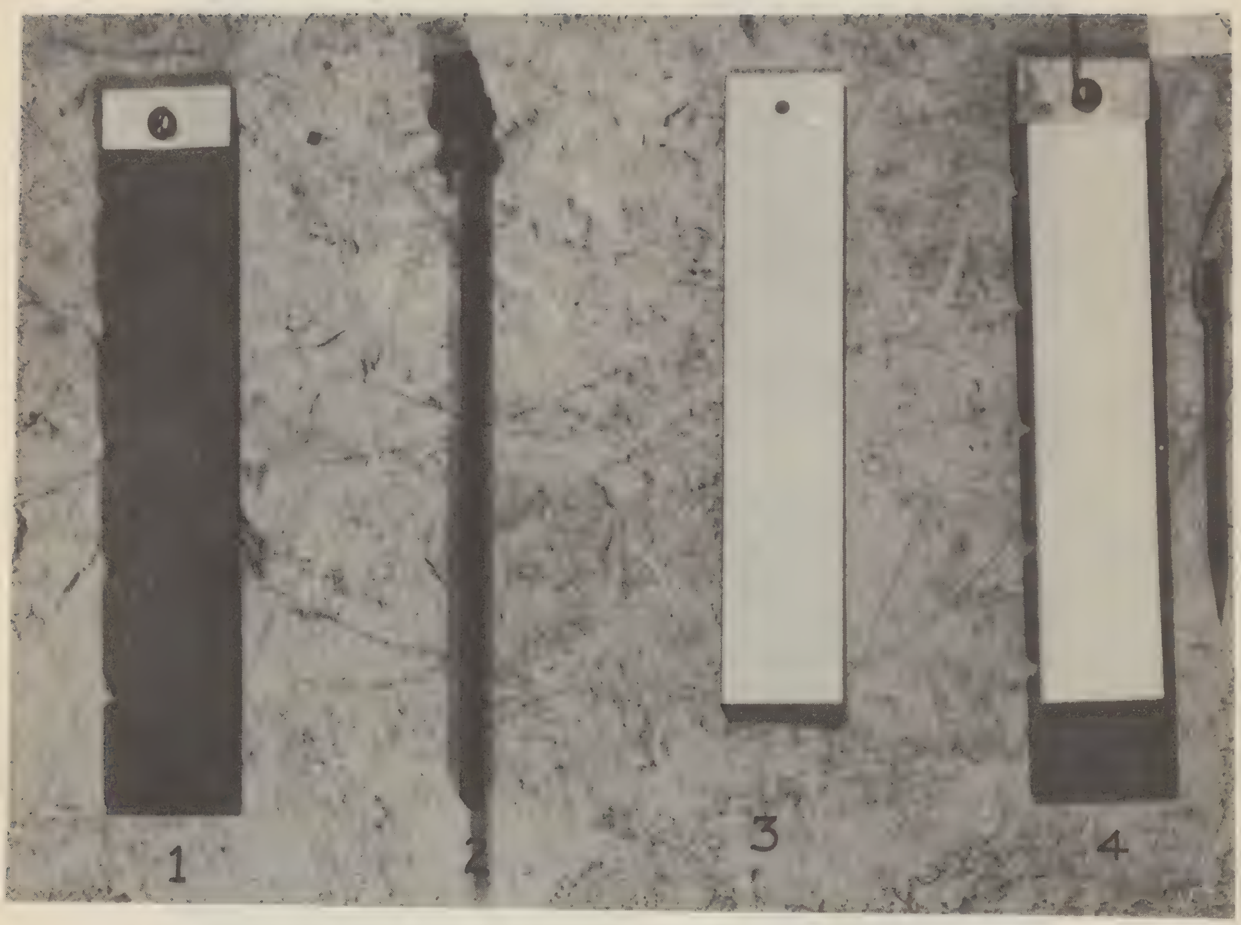
LUCKIESH-MOSS LOW-CONTRAST TEST CHART

EXHIBIT I



VIEW OF TEST TABLE, VIEWER (WITH AIRPLANE FIGURE), AND INDIVIDUAL INDICATORS

EXHIBIT J



PAD-AND-PENCIL RECORDING SYSTEM

1 - PAD HOLDER

2 - SIDE VIEW OF PAD HOLDER

3 - PAD (2" X 10½")

4 - ASSEMBLED PAD AND HOLDER
WITH ATTACHED PENCIL

EXHIBIT K

d. NVT FS - Film-Strip Model (Exhibits F-1 and F-2)*.--

(1) Regular bulb was replaced with a 3-candlepower automobile light bulb with adapter made from an old radio tube and an old projector bulb of the type to fit the bulb socket of the projector (Exhibit F-3)*. The bulb was burned at 4 volts by means of a storage battery and a low-voltage circuit tester.

(2) Light levels were obtained by graded filters which were fitted into regular film slides. These filters were made by trial-and-error method until the particular light levels desired were obtained.

(3) The test object was photographed, and the film of the object was placed (by means of an adapter) in the lens tube so that it was in focus and of the right dimensions when projected on a screen 25 feet away. The different positions were obtained by rotating the entire lens tube.

(4) This construction is not recommended for field use, but the practicability of the film strip was demonstrated.

e. NVT R1 (Exhibit G-1)*.

(1) This model used a radiant button 1-3/4 inches in diameter as a light source. The different levels of light were obtained by varying the distance between the button and viewing screen (Exhibit G-2)*.

(2) This model was not found to be practical because of the length of the test box necessary to obtain the desired levels of illumination on the screen. Also, the viewing screen at the higher levels was not uniform; a definite "hot-spot" was noticeable in the center.

f. NVT R2 (Exhibits G-3, G-4, and G-5)*.

(1) This model was the next step in design, using radiant plaques or buttons as a light source (specifications in Appendix IV).

(2) This tester has, as a light source, a radiant plaque, 100 square inches in area, especially developed for this study by the United States Radium Corporation, 535 Pearl Street, New York, N. Y. At 14 inches from the viewing screen, this plaque gave a brightness reading of .00020 foot-lambert. It was found that the various necessary light intensities for NVT-type test could be obtained by exposing smaller areas of the plaque. This was done by means of slides with holes of different sizes.

(3) The brightness level was directly proportional to the area exposed. Therefore, knowing the brightness for a particular exposed area, the area (or hole size) for any other desired level could be quickly obtained.

g. Mass-Testing Signaling System.--

(1) The signaling system designed (see Appendix II, Part II for complete description of wiring connections) can be used with any of the night vision viewers developed, such as NVX, NVT, NVT R2, and NVT FS. It can, of course, be used with any other night vision

* Exhibit F-1, p. 20; F-2, p. 21; F-3, p. 22; G-1, p. 23; G-2, p. 24; G-3, p. 25; G-4, p. 26; G-5, p. 27.

testing apparatus operating in a similar manner.

(2) This system consists of the rotating head (or master indicator), a BD-71 or BD-72 switchboard, the individual indicators, and enough W-130 or W-110 wire to make the proper connections.

h. Feldman Adaptometer.--

(1) The Feldman Adaptometer is an individual glare-reaction tester consisting of a very bright pre-exposure light and a dim stimulus or test light (Exhibits H-1, H-2, and H-3)*.

(2) The lights are carefully calibrated. It is important that the test light have the standard brightness. To assure this for the various voltages available in different localities, a three-way switch is built into the instrument.

(3) The pre-exposure field is 3" by 5½" and is made of opal glass. The intensity on this field using two 40-watt bulbs as a light source is 900 millilamberts.

(4) The rotatable stimulus or test light (bar) is 5/8" wide and 2" long. The intensity of this test light is .0018 foot-lambert.

(5) To make sure that the examinee's eyes were the proper distance from the test light a special FAS bench mount was built (Exhibits H-1 and H-2)*.

(6) The lamps providing the bright exposure field and the dim source are both standard.

i. Luckiesh-Moss Low Contrast Test Chart.--

(1) The Luckiesh-Moss Low Contrast Test Chart is shown in Exhibit I*.

(2) It is a chart with two columns of figures, ten pairs of figures in each column. The figures are in block form, and there are no 0's, 1's, 4's, or 7's.

(3) The contrast of the numbers with the background of the chart varies from the greatest degree of contrast in the upper left-hand corner to the least degree of contrast in the lower right-hand corner. The digits used have equal visibility.

(4) The percent of contrast varies from 36.0 percent at the upper left-hand corner to 6.8 percent in the lower right-hand corner. Each pair of figures differs about 1.5 percent in contrast from the figures on either side of it.

(5) The chart was illuminated using a movie projector with filters. The intensity of the light on the chart was .011 foot-lambert. Glare was eliminated as much as possible by placing the projector to one side of the chart.

j. Snellen Test.-- The conventional Snellen Test Chart was used under controlled conditions to test daytime visual acuity of certain personnel for correlation with their night vision ability. A standard film-strip projector was employed to obtain uniform lighting of 100 foot-candle intensity.

* Exhibit H-1, p. 28; H-2, p. 29; H-3, p. 30; I, p. 31.

15. ADMINISTRATION OF LABORATORY TESTS.—

a. General.—

(1) The plan of the laboratory and testing layout employed in the indoor mass testing is shown in Exhibits B and J.* The test rooms were as light-tight as possible. All openings were sealed and all surfaces painted flat black. A ventilating system was employed.

(2) The various brightness levels used in the several NVX and NVT tests described below are given in a Table of Illuminations, Appendix III.

b. Preparation and Orientation of Subjects.—

(1) When the examinees first entered the laboratory, they put on regulation Navy Polaroid goggles (for purposes of dark adaptation) and sat for fifteen minutes in the small anteroom in which the shades were pulled down.

(2) During this time the examinees were given the orienting talk, shown the individual indicators (dummy model), and a copy of the test object on which they were to be tested. Careful instructions were given every subject on the way he was to operate the indicator and the manner in which he was to employ "off-center" vision; charts were used for illustration. The importance of the work was emphasized, with frequent reference to reports from the combat zone, and the examinees were urged to try their best.

(3) At the end of the talk, six subjects at a time were shown into a small dark room, where they sat for fifteen minutes. The goggles were removed when they entered the room. They were warned against lighting matches or cigarettes. While one group was in the small dark room becoming dark adapted, another group was outside in the anteroom getting the orientation talk. In this manner a constant flow of examinees could be maintained. If goggles were not available, the examinees remained in the dark room a full half hour after the orientation talk.

(4) After fifteen minutes in the dark room, they were taken into the testing room. Each man had previously been assigned a number and took his seat in accordance with his number. A dim, red light was on in the testing room while the examinees found their seats. They were warned not to look upward but to stare at the floor when entering the room. As soon as all men were seated before their individual indicators, the red light was turned off and the man running the viewer turned it on at the level at which the test was to start.

c. Administration.—

(1) Four research staff members generally conducted the mass testing although at times three were able to do so. One instructor would give the orientation talk, two instructors handled the switchboard and recording, and the fourth one was stationed in the dark room to manipulate the viewer and to control the subjects tested.

(2) After all examinees had been seated, the operator of the viewer warned the timer that he was ready to start. The timer gave him the position of the test character – the direction in which it was to

*pp. 11, 32

point. The operator standing in front of the viewer adjusted the test object, asked the examinees if they were ready, and then stepped aside saying "Start." At the end of ten seconds, the operator, upon signal from the timer, said "Stop" and stepped in front of the viewer to shut off the light between trials.

(3) The examinees had previously been told that they must make up their minds concerning the direction of the test character and set their indicator arms quickly before the word "Stop" was given. Upon this command they were to take their hands off the indicator arm and leave it where it was. The operator warned any examinee who moved his indicator arm after being told to stop. The operator also prevented any talking among the examinees.

(4) Several seconds after the operator gave the command "Stop," the recorder turned the crank on the switchboard. If an examinee's indicator arm was in the proper position, his indicator or drop on the switchboard dropped when the crank was turned; if not, the drop would remain up. The recorder quickly checked all drops, recorded the scores, and then restored the drops to their upright positions.

(5) During the interval the operator changed the position of the test object. Ten seconds after "Stop," another signal to start was given.

(6) The sequence of positions of the test object was predetermined and typed on a card from which the timer read. Several cards, different in sequence, were used alternately on successive trials.

(7) A definite number of presentations was given at each level; the exact number of presentations given varied from one test to another. The number of levels of light used also varied from one test to another. At the end of the number of presentations agreed upon, the timer warned the operator to change levels. This continued throughout the number of presentations for that particular test, at the end of which time the examinees had a two-minute break. Upon completion of this break, the full series was repeated in exactly the same manner.

(8) The name of each man tested, his organization, the type of test, the date of testing, the time of day testing was conducted, the name of the man giving the orientation talk, and the names of the operator, timer, and recorder were kept upon recording sheets. A level-by-level score as well as a total score was recorded for each man.

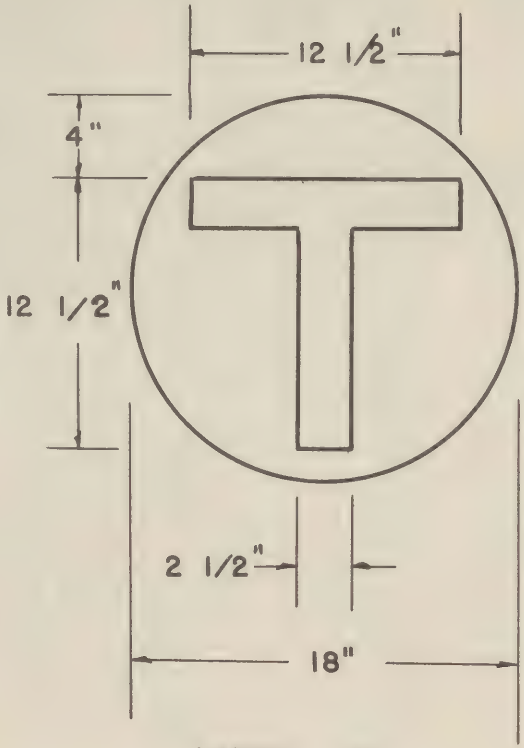
(9) It was the policy to give the subjects their scores at the end of the test - the number right out of the number possible.

d. Description of Tests.—

(1) NVX 1.— NVX 1 was administered using the regular NVX viewer. There were eight levels of light ranging roughly from one that everyone could see to one that nobody could see. The test character employed was a 1° Landolt Ring (Exhibit L) painted dull black. Across the front of the box a fine wire was stretched, and hooks were attached to the back of the Landolt Ring in such a fashion that the ring could be hung

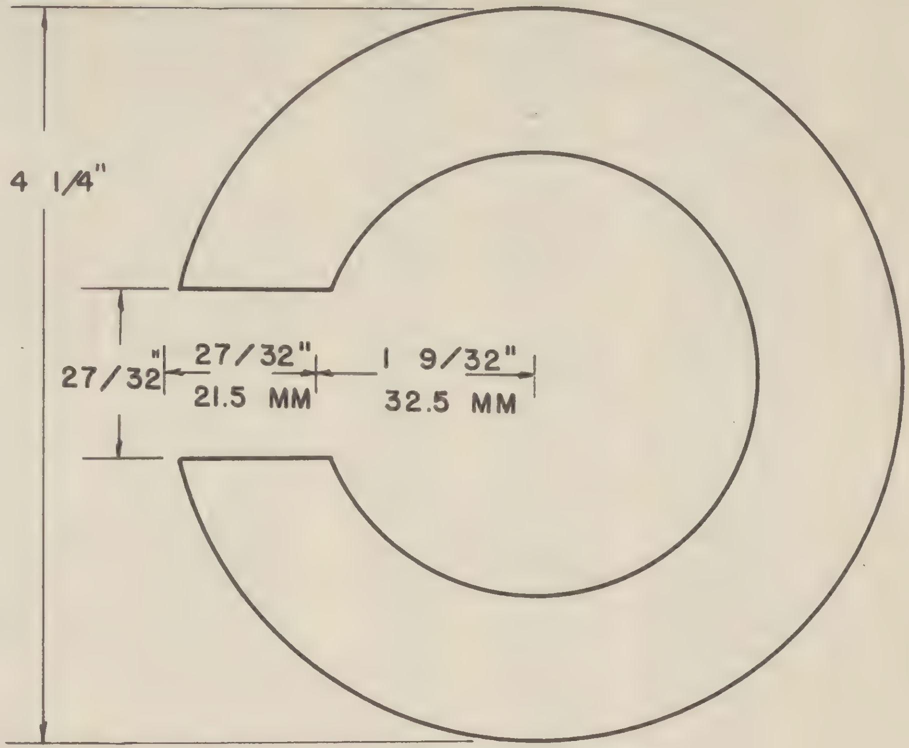
TEST OBJECTS

SCALE 1=8



LARGE T

SCALE 1=1



LANDOLT RING

VISUAL ANGLE ONE DEGREE AT 20 FEET

DRG NVX 106-A

EXHIBIT L

on the wire with the opening in one of eight positions: N, NE, E, SE, S, SW, W, or NW. In this and subsequent tests a 4° field was used with the examinees 20 feet from the field.

On this particular test the examinees were instructed to look any place they wanted to in order to see the ring. They were, however, instructed on the principles of off-center vision and told they would probably see the ring best by looking slightly off center.

During this test a master indicator was used, as described, by the recorder. After the timer gave the operator the direction of the test object, the recorder set the master indicator to the indicated direction. Upon the command "Stop" the recorder turned the crank on the switchboard, recorded scores, and then changed the arm on the master indicator when the next position of the test object was given.

(2) NVX 2.-- NVX 2 was administered in much the same way as NVX 1. The primary difference was in the size of the test character employed and the levels of light used. The levels of light were reduced and the ring was increased to a 2° Landolt Ring (8-1/2 inches in diameter).

Several preliminary runs were made on this test to determine the exact levels of light to be used. Earlier levels were much too difficult; the levels used on NVX 1 were too easy. A compromise was made and the levels used gave very satisfactory results.

The ring used on this test was also hung on a wire at first, although on later tests with this test character the rotating head was substituted. The installation of the rotating head eliminated any possibility of error in scoring. A misunderstanding between timer and operator no longer made any difference, since the actual position set on the rotating head automatically set the electrical system properly. All tests hereafter employed the rotating head.

(3) NVX 3.-- This series was to explore the effect of a fixation light, and NVX 3 was identical with NVX 2 with the exception of the fixation light. The fixation light, a pin point of red light, was attached 7° to the right of the test character, and the examinees were instructed to look at the fixation light at all times during the actual testing. Under no circumstances were they to look directly at the test character employed.

There was no possible way of checking on whether or not the examinees did fixate on this light, but most subjects tested were extremely cooperative. As the grades on this test did not directly influence their assignments, there is no reason for believing they did not follow instructions to the best of their ability

Several subjects reported great difficulty in seeing the test character when they fixated on the red light. In spite of this they were warned to keep looking at it in order that we might establish the effect of a fixation light on night vision work. It would at least make certain that the examinees were using "off-center" vision.

(4) NVX 4.-- The procedure used in the administration of NVX 4 was identical with that employed in the foregoing NVX tests. New factors in the test were the use of a cut-out test character and the optional use of a fixation light. The test character was a trans-illuminated 2° Landolt ring cut out from opaque, black material (Exhibit M). In previous tests, the test

characters have been black against a light background; here the character was light against black. Because of the darkness of the laboratory the black field was in effect unlimited. A red fixation light identical to the one used in NVX 3 was set up on one of the two trials, alternating with each group, but its use was optional on the part of the examinees.

(5) NVX 5.— NVX 5 was similar to NVX 4 in having a cut-out character, but the character employed was of the "airplane" type, with a maximum dimension of $8\frac{1}{2}$ inches (Exhibit M), rather than the Landolt-ring character previously employed. No fixation light was employed on this test. The rotating head was used, and the light forming the airplane came through the outline cut in the circular board placed in front of the light box.

(6) NVX 6.— The purpose of this test was to determine if the testing time could be reduced by reducing the exposure time. NVX 6 was the same test as NVX 2 with the exception of the change in time. On one series of forty presentations, the examinees were given only five seconds instead of the regular ten seconds exposure to determine the position of the test object. On the second series of forty presentations, the regular ten-second interval was given. The regular ten-second interval between exposures was maintained during both series of forty presentations.

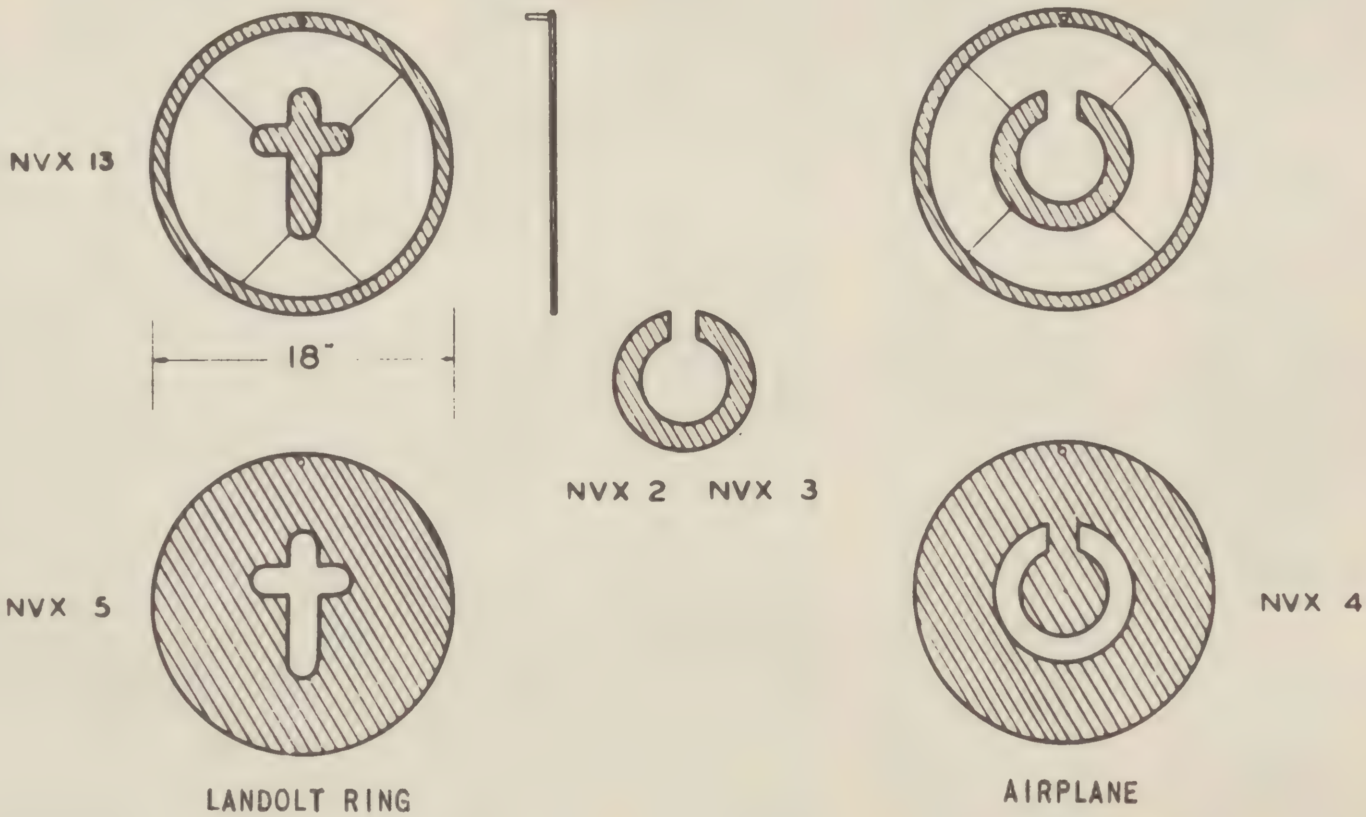
(7) NVX 7.— After an analysis of the scores obtained on NVX 2, 3, and 5, it was found that the big breaks in the scoring came only at levels 4, 5, and 6 of the 8 levels used on these tests. Although between the best and the poorest groups there was a marked difference at every level, it was found that the average of all men tested was nearly the same on the first three levels but dropped on each succeeding level until at the 7th and 8th levels scores were obtained which were nearly as low as pure chance scores.

To check the work done by these levels another test was run - NVX 7 - using only the 4th, 5th, and 6th levels and giving twenty trials at each level. After the examinee had taken 60 trials in this manner, he took 40 presentations of the regular NVX 2 series with 8 levels. This was to determine the relative ranking of the men using either 3 or 8 levels.

Some difficulty was encountered with men who reported insufficient dark adaptation at the first level (the 4th) and who got improved scores when they took the eight-level test mainly because they had a few trials at brighter levels before working down gradually to the discriminating levels. The indication was that although certain levels of light may be more discriminating than others, brighter levels probably must precede the lower levels in order to accustom the examinees to the lower levels.

(8) NVX 8.— NVX 8 was identical in procedure with the foregoing tests. The subjects were given 40 presentations of the 2° Landolt ring with the NVX 2 levels of light and then given an additional 40 presentations at the same levels using the airplane figure (Exhibit M).

The purpose of the test was to determine the difference existing, with regard to visual distinction, between a test character such as the Landolt ring and one such as the airplane figure.



TEST OBJECTS

SCALE 1/10 = 1

DRG NVX 106

EXHIBIT M

(9) NVX 10.-- NVX 10 was given using a procedure identical with that followed for NVX 2. The difference was in the type of test character used on the second series of 40 presentations. The regular 2° Landolt ring was used for one series of 40 trials; a Landolt ring with a 25% larger opening was used for the second series of 40 trials. The purpose of the test was to determine whether or not a larger opening made visibility easier.

(10) NVX 13.-- To determine the role of visual acuity in night vision and the effect of ease of vision on the scores obtained on the NVX series, NVX 13 was given. The test procedure was identical with that followed on previous NVX tests. The difference was in the nature of the test character employed. The airplane figure was used (Exhibit M)*. The examinees had to determine in what direction it was pointing or flying. They were all given careful instructions to consider the short part of the bar above the cross arms as the front of the plane, to put their indicator arms in the direction thus indicated, and to proceed as on NVX 2 the rest of the time.

As the figure was easier to see than the Landolt ring, it was found necessary to use only the bottom six levels of light employed on NVX 2. The top levels were readily distinguishable while the bottom levels were barely visible to anybody tested.

One reason for the apparent visibility of the airplane figure was the fact that if the examinee could see the bar at all he already had the direction localized in one of two positions whether or not he could see the cross arms on the bar.

(11) NVT 14.-- NVT 14 was administered for two reasons. The first was to determine the effectiveness of the newly designed battery-operated night vision viewers for field use. The second was to determine the effect of the size of the field upon scores obtained.

Two separate viewers were used on this test. One series of 40 presentations was given using a viewer with a 4° field; the other 40 presentations were given on the second viewer with a 6° field. Both viewers operated from battery current rather than house current, which was used on all previous NVX series. The viewing screen on both boxes was also different from the other series. White tracing cloth was used rather than the opalescent glass previously employed. A 2° Landolt ring was used as the test character in each case.

(12) NVT 15.-- NVT 15 was administered using the NVT (battery-operated) viewer with a 4° viewing screen (white tracing cloth). This test used only five levels of light covering approximately the same range as the eight levels used on earlier series. A 2° Landolt ring was used as a test character.

Eight presentations were given at each of the five levels - a total of forty presentations in each series. Every examinee took two series or a total of eighty presentations.

(13) NVX 16.-- As a further test of the role of visual acuity in night vision, NVX 16 was given. A test character resembling a large T (Exhibit L)* was used to reduce the amount of visual acuity required to a minimum. The test character was 2-1/2" wide, the cross arms were 12-1/2" long, and the body was 12-1/2" long.

* Exhibit M, p. 41; L, p. 38.

It was thought that inasmuch as some of the men tested had faulty daytime vision uncorrected by glasses, the lowness of their scores might be due to sheer inability to see the test character regardless of the levels of light used. Several men tested had eyes 20/50 or worse and did not wear glasses. Even a small amount of astigmatism might blur the opening in the Landolt ring to such an extent that the perception of the opening would be impossible even at the highest levels.

The first trial on this test was given using the normal ten-second interval between start and stop. The second series of presentations was given using an interval of only seven seconds. This was to determine if the time of giving the test could be shortened. If large numbers of men are to be tested, a short test is extremely desirable.

(14) NVT FS.— The NVT film-strip model was given using a standard film-strip projector with certain modifications (Exhibit F-1)*. While actually a slide test, it was designed to explore the practicability of the film strip.

Eight presentations were given at each of five levels of light, a total of forty trials, as shown in Table of Illuminations (Appendix III).

A 2° image of a Landolt ring test character was thrown on a 6° field twenty feet in front of the examinees who operated scoring indicators identical with those used on previous night vision tests.

The testing procedure was otherwise identical with that described for earlier night vision tests.

(15) NVT PB.— To ascertain the worth of the NVT design in simplest form, a NVT tester was constructed from a salvaged quartermaster clothing packing box (Exhibit E-1)* and operated from a storage battery in the usual manner. The 2° Landolt ring was employed, and five levels of light were used. The levels of light used on this test and those employed on the film strip were practically identical.

The test procedure employed was identical with that employed on previous NV tests. Forty trials, eight at each level, were given on this model immediately after the examinees had taken the film-strip test.

(16) NVT R1.— No testing was done with this model.

(17) NVT R2.-- NVT R2 was given using as the source of illumination a self-illuminated radium plaque especially developed for the purpose (Exhibit G-3)*. The airplane figure was used with six levels of light. The levels of light were obtained by means of slides with graded-size holes between the radium source and the viewing screen.

The purpose of this test was to determine if a night vision test could be constructed using a self-illuminated radium source as the source of illumination. If it could be utilized, it would obviate the use of either house current or storage batteries and the difficulty of control involved in the use of either.

The procedure used in the administration of the test was identical with that used on NVX 13.

(18) Tests with Feldman Adaptometer.— The Feldman Adaptometer (Exhibit H-3)* is an instrument designed to measure the rate at which dark adaptation takes place and assumes that rate of dark adaptation

* Exhibit F-1, p. 20; E-1, p. 17; G-3, p. 25; H-3, p. 30.

predicts night vision ability. This is questionable. It was primarily intended to "screen out" night-blind individuals from the normal and is not intended as an instrument to be used for fine classification work.

In the administration of the test, the person being tested was exposed to the pre-exposure light for a specified period of time. During this period he was instructed to shift his eyes slightly from time to time to insure complete bleaching of the entire visual field. At the end of the pre-exposure period, the light was snapped off and the test light (bar) or rotatable stimulus was turned on. This test light (bar) was set in one of four positions--horizontal, vertical, diagonal to the right, or diagonal to the left. The subject was required to tell the examiner the direction in which the light (bar) was set. If the examinee made a wrong judgment the first time, the light (bar) was rotated to a new position by the examiner and the test continued until the correct position of the light (bar) was determined.

When the pre-exposure light was shut off, the examiner took the subject's right forefinger and placed it on the small metal knob to the right of the test light (bar). The subject was to use his forefinger as a fixation point, so that he would use peripheral vision in searching for the test light.

After turning off the pre-exposure light, the examiner started a stop watch and kept it running until the examinee reported correctly the position of the test light (bar). The time taken to determine the position was the score on the test.

The intensity of the test light (bar) being very small, the time taken to identify the position varied from one to three minutes. Any subjects who required over five minutes were considered as pathological cases.

Three separate series were run using the Feldman Adaptometer. With a 900-millilambert pre-exposure, the dark adaptation would necessarily be principally cone adaptation. Therefore limited tests were made with pre-exposures of weaker intensities. (The intensity of the test light was also reduced in these tests.) The three series are:

(a) Feldman I.-- In this series the pre-exposure light was supplied by two 25-watt bulbs, with an inserted filter which gave a light field of 560 millilamberts. The intensity of the test light (bar) was reduced to .00068 lambert. The subjects were given a 3-minute pre-exposure period. Subjects were given only one trial.

(b) Feldman II.-- In this series the pre-exposure light was supplied with two 25-watt bulbs with an inserted filter which gave a light field of 150 millilamberts. The intensity of the test light (bar) was .00068 foot-lambert. The subjects were given a 5-minute pre-exposure period. Subjects were given only one trial.

(c) Feldman III.-- In this series, the instrument was operated at the brightness levels in the standard design, using two 40-watt bulbs in the pre-exposure field, without a filter, producing a field of 900 millilamberts. The brightness of the exposure

light (bar) was .0018 foot-lambert. The pre-exposure period was 4 minutes. Subjects were given two trials. On the first trial they fixated their eyes on the small metal knob to the right of the exposure bar and saw the test light (bar) in the periphery of their eyes. On the second trial the subjects were instructed to move their eyes slowly between the two metal knobs on either side of the test light (bar) so that their eyes crossed the area of the test light (bar).

(19) Luckiesh-Moss Low Contrast Test Chart.— The Luckiesh-Moss Low Contrast Test Chart (Exhibit I)*, previously described in par. 13h, is a test designed to be given at 0.01 foot-lambert, where seeing depends almost entirely upon rod vision. By picking out individual differences in contrast sensitivity, it is expected to predict individual ability to see at night.

The chart was hung at eye level (subject seated) on a wall of the darkroom, in a protective case. To insure that the examinee's head would be ten feet from the chart, a table and a chair with a head rest were set up. The chart was illuminated with a standard type movie projector fitted with a filter to insure the proper brightness. The brightness averaged .011 foot-lambert. The projector was placed eighteen feet from the chart at an angle of about 30° to reduce or eliminate glare from the light coming in. A standard telephone headset, HS 19, was mounted on the table in front of the subject to enable the recorder outside to hear the subject's words.

The subjects were given a short orientation talk, supplemented by use of a dummy chart, and then given a 30-minute dark-adaptation period before taking the test. This dark-adaptation period varied from 30 to 40 minutes for different subjects, depending upon the order of testing.

At the end of the dark-adaptation period the subject was brought into the testing room and seated. Dim red indirect illumination was used to guide him to his seat. When the examiner was sure the subject was ready, the red light was snapped off and the chart was illuminated. The subject was told to start at the upper left-hand corner, read down the left column, then start at the top of the right column, and read down the right column until he was unable to distinguish the figures. When the subject could read no further, he was given a one-minute break. Then the test was repeated. Each subject was given three trials. The subjects were told to read the figures distinctly because their scores were being recorded through the telephone headset. The recorder wrote down on the recording sheet every figure read by the examinee. A photographic copy of the chart was placed in front of the recorder to make certain that the examinee did not skip a line in his reading.

If a subject stopped reading, he was urged to continue, given hints on off-center vision, and told to guess if necessary. At the end of three trials, the lights were turned on and the examinees dismissed.

16. <u>OTHER LABORATORY TESTING PROGRAMS</u>.—

a. Field Test of NVT with Troops.

(1) To test the general field effectiveness of the night vision testing procedure, it was deemed desirable to have the test administered by an organization on the post utilizing its own quarters, facilities, and personnel for administering the test. The 401st Field Artillery Group volunteered for the purpose.

* p. 31

(2) Since the viewer and the scoring apparatus were already available, they were utilized, although they could have been built by the organization itself. These were the field model NVT and the mass-testing signaling equipment, all made from T/E, TBA, and salvage items. All work such as orientation, administration, and technical maintenance was carried on by the organization's personnel.

(3) The 401st Group, consisting of four Field Artillery Battalions, gave the test to 770 men, most of them drivers. The testing program lasted for several weeks, being carried on when the men were available.

(4) Four officers, one from each battalion, were given an orientation talk by a member of the Research Department. They were familiarized with the type of orientation talk to be given, the procedures to be followed, and the use of the scores. These officers in turn selected personnel from their organization, oriented them, taught them how to give the test, and supervised the administration of the test. The test used was identical with NVT 15.

(5) At the conclusion of testing, the scores of all men tested were sent to the Research Department, and classifications were made up and sent back to the group. This work could easily have been handled by the personnel of the organization, but the scores were desired by Research for experimental purposes.

(6) The test given was the same as NVT 15. The organization blacked out the attic of the barracks for administering the test. Research personnel installed the viewing apparatus and the scoring system.

b. Pad-and-Pencil Test.--

(1) The purpose of this test was to determine the value of a pad-and-pencil recording system in mass testing. This series was given only to members of the 688th Field Artillery Battalion and was never administered to the experimental group. It was identical with NVX 13 except for the scoring system. This system had been developed and checked previously by means of tests on miscellaneous personnel.

(2) Each examinee was given a pencil and a board (Exhibit K)* to which a pad of paper was attached. The board had five notches on the left side. The examinees were instructed to determine the position of the test characters on the viewing screen in terms of the figures on a clock; i.e., the test character would point to 12, 3, 2, 5, 6, 8, 9, or 11. Once they had determined the clock position of the test object they were to write down that number opposite the first notch on the first page. When the test character was changed to a new position, they wrote the new position down opposite the second notch. Since only five presentations were given at each level, the operator told the examinees to turn over the page when he switched levels on the viewing screen.

(3) In this manner, scores were obtained for five presentations at each of six levels. The sequence of positions of the test character had previously been agreed upon. At the conclusion of the test the pads were collected and scored by hand.

* p. 33

(4) Each examinee took thirty trials using the pad-and-pencil scoring system, and thirty more trials using the regular indicator and switchboard scoring system in order to determine the relative effectiveness of the two systems.

(5) There was no noticeable difference in reliability between the two systems of scoring, but the administration of pad and pencil was more difficult. The pad-and-pencil system may be utilized wherever it is impracticable to set up a wiring system such as that required by NV mass-signaling system.

c. Acceleration of Timing on the NVX Test.--

(1) NVX 2 was administered to approximately 100 miscellaneous subjects. Only 7 seconds was allowed for each presentation, with an interval of 8 seconds between presentations.

(2) The object of this test was to determine if a time interval shorter than 10 seconds could be used.

d. Administration of Snellen Test.--

(1) Because the Snellen ratings of the main experimental group used in this study were possibly unreliable, certain members of another organization, the 342nd Armored Field Artillery Battalion, who had been tested on NVX 13, were given a Snellen test as well.

(2) The test was administered by staff members in the darkroom, using a standard Snellen Chart illuminated by 100 foot-candles of light from a standard projector. The procedure followed was suggested by the eye specialist of the post hospital.

(3) Of the 76 men tested, 36 had received very high scores on the NVX 13 test, and 40 very low scores. The average Snellen score for those with the best night vision was 20/23, and the average Snellen score for those with the poorest night vision was 20/24, an insignificant difference.

17. THE TRAINING CIRCULAR 44 TESTS.--

a. The optional test for night vision described in paragraph 6, Section IV, War Department Training Circular No. 44, 24 July 1942, was given several trials under different conditions. This was done

(1) To make certain that the early judgment of its dubious value was not in error.

(2) To explore the possibilities of its development into an efficient test.

b. Extract from Training Circular 44, 1944.--

"6. TEST FOR NIGHT VISION.-- a. The following rough measurement of night vision may be made by testing men outdoors on a dark night before the moon has appeared. A night will be considered too bright for test purposes, if, after 25 minutes of dark adaptation, individuals can read small newspaper type without the assistance of light.

"b. Mount on a post at the end of a level space 5 yards wide and 40 yards long and away from all artificial light a black target on which is a movable white strip, 6 by 24 inches. Mark off distances from the target at 5-yard intervals. After the person to be tested has been kept away from all artificial illumination for 25 minutes direct him to walk slowly from the far end of the test area toward the target. The distance at which he is first able to identify correctly the position of the white strip is noted. While the person being tested is walking back for another trial, the position of the white strip is changed. Several trials are made. Correct recognition should take place at an average distance of not less than 20 yards from the target."

c. Training Circular 44.-- Test TC 44-I.

(1) To obtain an example of results under field conditions, the control battery was told to carry out the provisions of the Training Circular according to their own interpretation, with apparatus constructed by themselves, under their own supervision. Participation of our research group was to be as observers and to record the various conditions under which the test was run.

(2) This battery complied and tested 91 of its men over a period of four nights. The initial night's run was discarded because of adverse lighting conditions, and the men were retested. Levels of brightness are given in Table of Illuminations and are practically identical for the three nights of testing.

(3) The test target was constructed as described in the Training Circular; the test location was selected within a grove of trees. The approach to the target was cross-lined with white every five yards. Every ten yards a number was placed to indicate the distance from the target. The target was supported against the base of a tree.

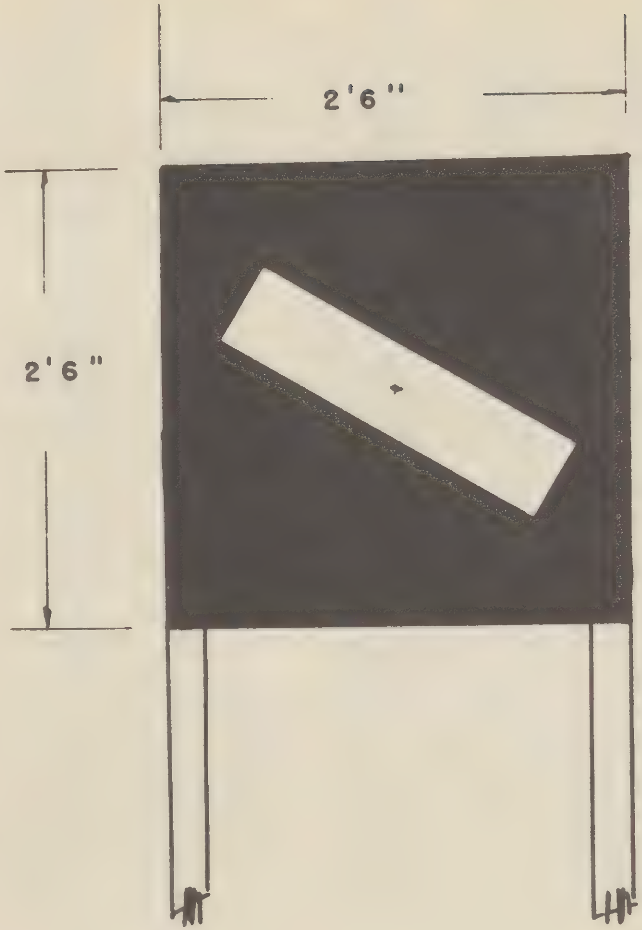
(4) The test was administered by the battery's noncommissioned officers. On each night the men from Battery A assembled in the woods in groups of about thirty. They were forbidden to smoke or light matches for a thirty-minute period before they were tested; however, the nearness of this area to a traveled road caused car lights occasionally to flicker into the area. A recorder was present to take each man's name and record his score as it was called out. The test followed generally the instructions of the circular, but a number of examinees received only one trial. The average distance for recognition was 65 yds.

(5) Difficulty was encountered when several men looked in the wrong direction. It is possible and probable that some of the judgments were nothing more than correct guesses.

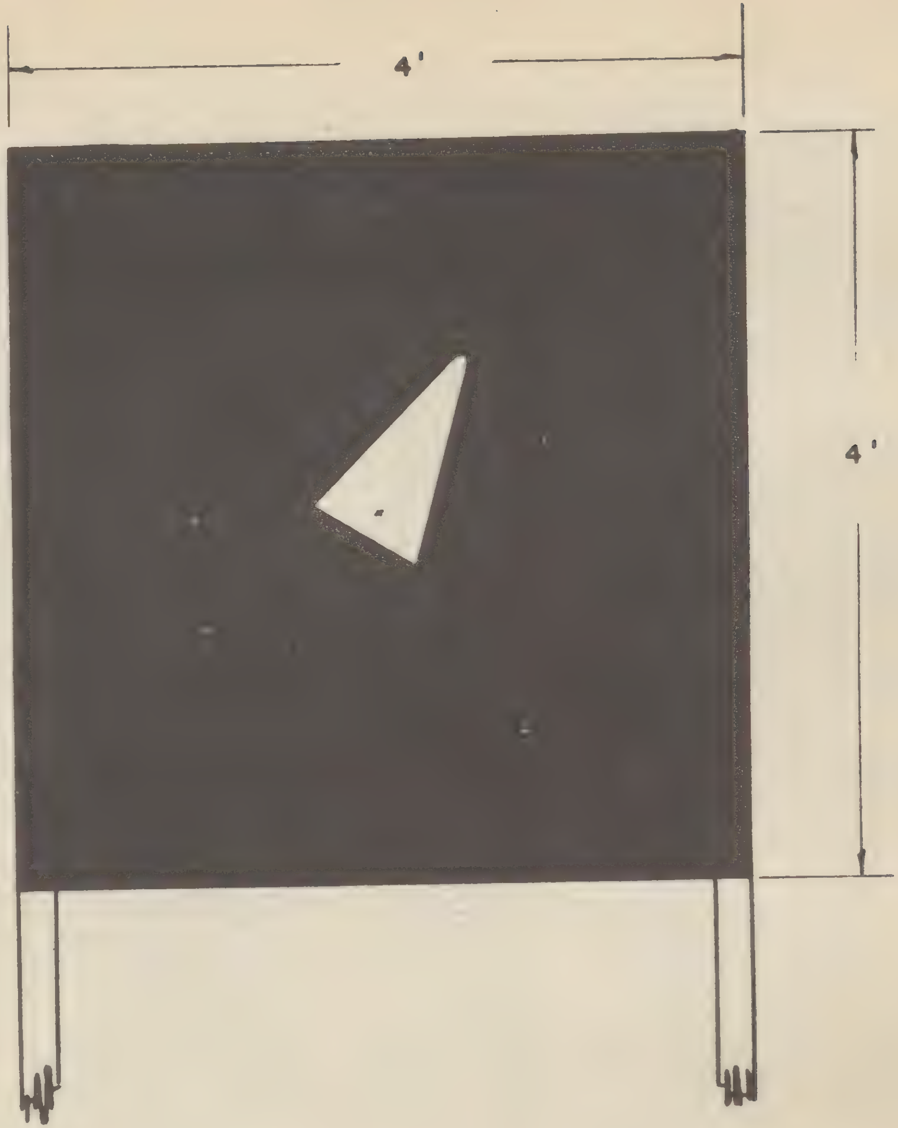
d. TC 44-II.--

(1) Because some maintained that the TC 44 test, with modifications, was still an adequate test for night vision, a rerun of this test and of a suggested modification (TC 44-Z) was directed. Both of these are illustrated in Exhibit N.

(2) These tests were run under the best conditions--the area used was far removed from all interfering lights. Only the best possible time was



TC 44 TEST BOARD AND FIGURE



TC 44-Z TEST BOARD AND FIGURE

Scale 1" = 1'

EXHIBIT N

selected. The night was clear, with bright starlight, no clouds, virtually no wind, no haze, and no sky glare. The sky brightness, measured at zenith, remained constant throughout testing.

(3) The test was administered by experienced officers of the research staff. Three separate targets were set up on three adjacent lanes, and the approaches to each target were cross-lined with white lime every five yards and numbered every ten yards.

(4) The examinees started walking slowly toward the target until they could make a judgment as to the pointer's position. If the examinee was correct, he stayed at that spot and made two more judgments. The pointer's direction was changed each time by a man who stepped in front of the board while turning the pointer. If both of the examinee's judgments were correct, the examiner entered this distance on his card and the test was completed. If, however, the examinee was unable to give three correct judgments at that position, he was moved forward to a distance at which he could give three consecutive correct judgments. All distances at which an examinee made at least one correct judgment were recorded on his card, but the test was not completed until the examinee had made three correct judgments at one distance.

(5) A drawing of the backboard and the test object for this test is shown in Exhibit N.*

(6) This test obviated many of the criticisms of TC 44-I. The possibility of guessing the correct positions three times in a row was relatively slight. It was fairly safe to assume that the distance at which the examinee could read the position correctly three times was the one at which he could first certainly see the pointer.

(7) The tests were all given on one night and were given quickly and efficiently. The sky was very uniformly illuminated during the entire testing period. The illumination during this test was checked, and the levels found are in the Table of Illuminations, Appendix III.

e. TC 44-Z.--

(1) This was a TC 44 test modification suggested by the Training Aids Section of the school. It was administered in exactly the same manner, in the same area, and at the same time as TC 44-II. The only difference between the tests was in the target. TC 44-Z had a triangular pointer with the broad base of the triangle at the center (Exhibit N).* Thus, since the point of the triangle could point in one of 8 directions--N, NE, E, SE, S, SW, W, and NW--the chance factor was decreased.

(2) As in TC 44-II the examinee had to make three correct judgments at one distance before completing the test.

(3) The courses and the personnel tested were the same as those used on TC 44-II. The triangular pointer was painted white and the background board a dull black. The pointer was at about shoulder level. This test proved to be the least valuable of the TC 44 tests.

* p. 49

18. OUTDOOR PROCEDURES USED AS CRITERIA FOR VALIDATION OF TESTS.--

a. The whole problem of criteria was unsettled at the beginning of this study. By criteria for night vision is meant suitable outdoor tests given at night, the score on which would represent fairly the quality of a soldier's performance under field conditions at night. The scores then can be used as standards to which indoor tests can be compared, or correlated, for validity.

b. No satisfactory criteria of night vision performance in the field had been developed in previous studies made on adaptometers or other night vision testers. The Adjutant General's Office laid great stress on this phase of the work.

c. The problem of devising satisfactory criteria, which could be measured, was a very difficult one. The members of the research group pooled their ideas in the first attempt to develop criteria. These ideas included:

(1) An observation post set-up from which examinees were to make observations and identifications of various objects and events in a given zone and in a definite sequence was first considered. This idea was abandoned because it raised gross administrative difficulties and introduced extraneous factors. The Armored Forces Medical Research Laboratory recently attempted a similar test, the results of which they seemed to consider not entirely satisfactory.

(2) A night driving obstacle-course test, which was attempted, was abandoned because of scoring difficulties. Scoring depended largely on the individual judgments of the examiners.

(3) Considering the above attempts and practical experience from studies in the field, the staff believed that a night walking obstacle course would eliminate many of the interfering extraneous factors. A combined obstacle and observation course was adopted. See the description below of Observation Test I.

(4) Various tests of proficiency in battery duties at night were abandoned because of lack of time and the belief that the additional variables of skill and training would complicate the measurements.

(5) Several experiences with night vision courses showed that the biggest objection to most of them, exclusive of administrative and subjective difficulties, was the fact that many items, set up as obstacles or for observation, were not differentiating the men. Everyone was getting them wrong or right. As a result, Observation Test II in which all items on the test were differentiating was conceived. See the test description below.

(6) No single outdoor test can be expected to provide a thoroughly satisfactory criterion of night vision ability, because of administrative difficulties and lack of control over outdoor illumination. However, a combination of several such tests seems to provide fairly accurate measures and appears to be acceptable. Observation Test II is the best single approach to the problem since it actually is a battery of ten tests, each of which provides two scores.

19. OBSERVATION TEST I.--

a. This test was given at Ft. Sill in an area directly behind a string of bluffs along a river bank. Thirty objects were laid out on a horseshoe course, as shown in Exhibit O. These objects, depending upon their size and ease of visibility, were placed at various distances from the walking part of the course. Various types of backgrounds were selected; part of course was in the clear and part in heavy woods. As will be seen in Exhibit O, all objects were equipment common in the Field Artillery.

b. The examinees, 69 in number, were brought to a field close to the testing area about one half hour before testing started. During this time dark adaptation took place. A dispatcher took the men to the starting line at the top of the hill and sent them down to the testing area at the rate of one man every two minutes. At the starting point, they met an examiner who walked along the course with them. The examiner took the examinee's name on a filing card and instructed the man to walk along the white line until he came to an arrow pointing in the direction of the object to be recognized. The examinee was to look along the arrow and describe or name the object he saw there. If the man could either name the object or describe it in detail, the examiner made no mark on his card and the examinee moved to the next arrow. If, however, the examinee could neither describe nor name the object, the examiner marked his card. At the end of the course the examiner sent the examinee back to a waiting truck, counted the errors, subtracted the number of errors from the total number of objects, and gave the examinee a score.

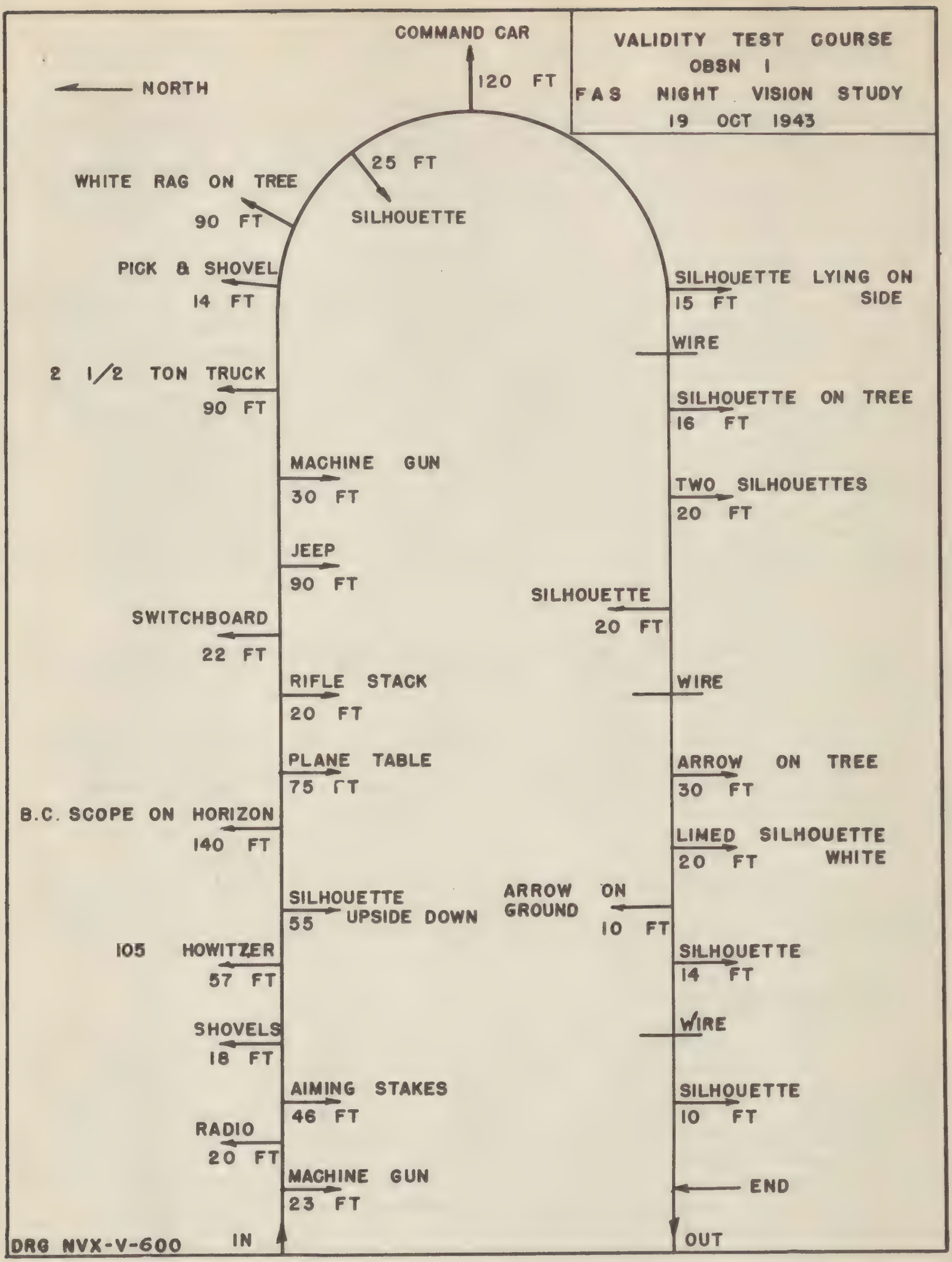
c. The examinee's score was the total number of items recognized. There was no attempt made to determine which objects each examinee missed; therefore no item-by-item score on this test is available.

d. Difficulties arose in the scoring system. It is possible that different examiners graded with different degrees of severity. Some made the examinees tell them the direction vehicles and silhouette dummies were pointing while other examiners asked the examinee to tell them only whether the object was a vehicle or a silhouette.

e. The illumination was fairly uniform, but distant flashes of lightning, a very gusty wind, and clouds of dust were extremely detrimental. The men came in two groups about one hour apart to prevent them from having to wait too long before taking the test.

20. OBSERVATION TEST II.--

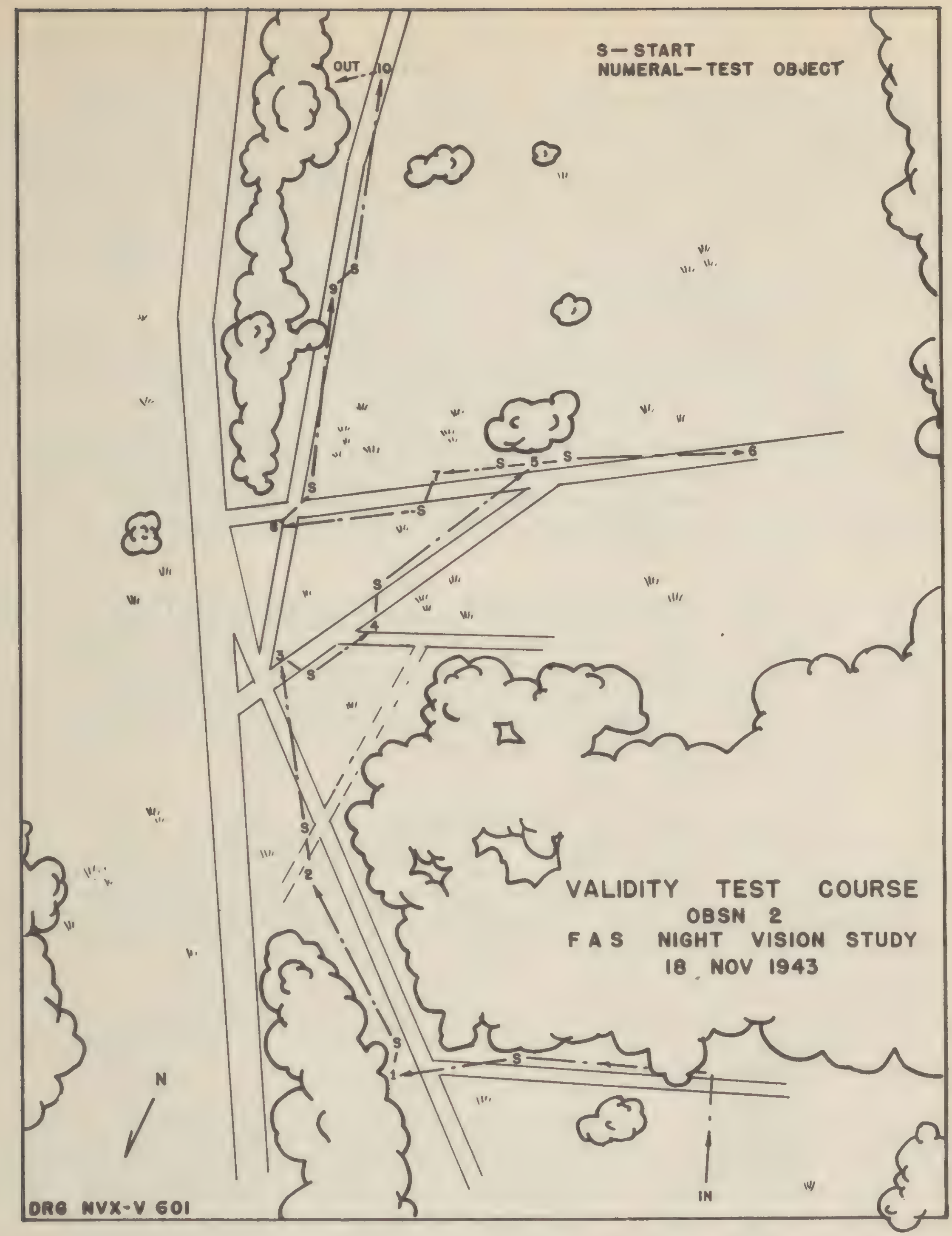
a. This test consisted essentially of 10 presentations at night of objects familiar to all Field Artillery soldiers who have completed basic training. The objects were placed out-of-doors in varying positions and with varying backgrounds, including grass, dirt roads, trees, bushes, combinations of the foregoing, and sky. Each was placed along a course in series as shown in Exhibit P. The approach to each of these targets was a crossed line made with white lime every 5 yards and numbered every 10 yards to indicate distance to the target. The examinee started at the first object; when he completed it, he moved to the second; and he continued in this manner until he had finished the course. At the beginning of the course each man received a card with his name on it and spaces for recording his scores on each test object. He gave the card to the examiner for each test object, and his score in yards was entered on the card when he completed the course.



VALIDITY TEST COURSE

OBSERVATION TEST I

EXHIBIT 0



VALIDITY TEST COURSE, OBSERVATION TEST II

TARGET NO.	OBJECT	TARGET NO.	OBJECT
1	4-Ton Truck (front view)	7	2 Dummies, 1 standing, 1 kneeling
2	Command Car (side view)	8	Command Car (rear view)
3	155-mm Howitzer (side view)	9	Half Track (side view)
4	50-cal Machine Gun ground mount	10	1/4-Ton Truck (side view)
5	2½-Ton Truck (side view)		
6	155-mm Howitzer (side view)		

EXHIBIT P

b. An officer of the research group was stationed on each course to conduct the examinee along the test course from starting point to target. The examinee started walking slowly toward the test object until he first perceived an unrecognized object different from the natural surroundings. He was encouraged by the officer to scan and use "off-center" vision. This perception distance was recorded. The examinee continued slowly toward the test object until he could either describe its class, i.e., vehicle, gun, and the like, or could name it specifically, i.e., 155 howitzer, 2-1/2-ton truck, and so on. He had to identify the object specifically before his final score was entered.

c. At the last object on the course the examiner in charge collected all of the cards and sent the men to a waiting truck. Examinees completing the course had no opportunity to communicate with subjects waiting.

d. The examinees were forbidden to stoop and silhouette the object against the sky or move off the lined path to get a side view of the object. It was sufficient for them to describe the test object by some adequate detail. In spite of the fact that all the test objects were Field Artillery equipment, some examinees would have been unable to name them.

e. To eliminate subjective influence as much as possible, each target was manned by an individual member of the research staff who tested solely on that particular target. Prior to any testing, the staff members were carefully schooled in their duties, received identical orientation, and made a trial run, utilizing personnel of the 285th Field Artillery Observation Battalion. This trial was on a misty, cloudy night of half moonlight, and the moon was partly obscured at various times during the evening. Therefore, scoring on the trial run was deemed worthless.

f. Forty-eight members of the experimental group, Battery A, 694th Field Artillery Battalion, were given the test on a moonless, starlit night. The test took approximately 4 hours. While it was realized that a larger number of examinees was needed for validation purposes, about fifty were all that could be run through in one evening with adequate time. The test was thoroughly controlled and the interest of subjects maintained sufficiently to give excellent results.

g. The scores obtained were in yards. An individual's scores were the total yardage necessary (1) to perceive the object and (2) to recognize and identify the object correctly.

h. On a subsequent evening, a test of another 50 examinees, not of the experimental group, but of the 285th Field Artillery Observation Battalion were tested. Some of these men had participated in the first trial run. Difficulties were encountered. First, the lights at a ball park on the post were on during the test. The glow raised the levels of brightness in all parts of the obstacle course and probably diminished them when the lights were turned off (see Table of Illuminations). Furthermore, the examinees had been out on a problem in the field all the previous night and had worked all day before the test. Hence, they were disgruntled, disinterested, and tired. In order to get them back to their barracks as soon as possible, the test was speeded up and finished in almost half the time of the previous testing. This run was unproductive of results.

21. STATISTICAL METHODS EMPLOYED.--

a. The procedures used were approved by the Technical Section of the Classification and Replacement Branch of The Adjutant General's Office.

b. Statistical studies were run as tests progressed to obtain information to guide further developments.

22. GROUPING OF TEST SCORES.--

a. Raw scores ordinarily mean very little to most people. It was thought desirable to group the men into five groups from best to poorest.

b. The grouping of scores was arbitrary. The men were divided into groups on the assumption that the scores would approximate a normal distribution curve. The means and standard deviations on each test were computed, and scores were grouped by standard-deviation intervals. It is a convenient classification which a unit commander can use to assign personnel to night duties.

c. For practical use in the field, it is suggested that this procedure be modified as follows:

(1) Test the entire group, battalion or larger; retest the lowest 15%.

(2) Use scores of entire group, including retest scores of the lowest 15%. Correct retest scores by subtracting 2 points on a 40-presentation test or 4 points on an 80-presentation test. Then, establish the final grouping as follows:

Class I - (Superior) the highest 10%
Class II - (Above average) next 20%
Class III - (Average) middle 40%
Class IV - (Below average) next 20%
Class V - (Poor) the lowest 10%

(3) Where standard laboratory conditions are possible, as in replacement centers and at large posts or stations, a standard grouping procedure can be used as a basis for pre-selection of recruits and trainees for assignment. All other factors being equal, individuals in the first three groups should be used as replacements in combat units, and those with inferior night vision sent to non-combat units.

23. DISCUSSION OF RESULTS AND EVALUATION OF NIGHT VISION TESTS.--

a. The statistical data to which the following discussion refers will be found in Exhibit Q-1. An explanation of the meaning of correlations is included therewith (Exhibit Q-2).

b. Reliability

(1) Split-Half Reliabilities.

(a) There is little difference between NVX 2, 4, 13, NVT 14, and NVT 15 in reliability. The split-half reliabilities of these tests are all between .89 and .97 for an 80-trial test. The

Test	Variable Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
NVX 1	1	.85																			
NVX 2	2	.76	.85																		
NVX 3	3	.62	.86	.84																	
NVX 4	4	.74	.88	.88	.93																
NVX 13	5	.70	.80		.80	.90															
NVX 16	6	.46	.69		.82	.87	.90														
NVT 14S	7																				
NVT 14L	8																				
NVT 15	9	.75	.87		.83	.85	.75			.91											
NVT FS	10		.66							.74											
NVT PB	11		.72							.76	.81										
Original Feldman	12												.44								
Revised Feldman	13		.04											.61							
Luckiesh-Moss	14		.42													.31					
TC 44-I	15	.49	.49		.44	.70	.43			.39											
TC 44-II	16	.41	.53		.50	.65	.50			.63						.16					
TC 44-Z	17	.39	.36		.49	.45	.31			.41						.10	.42				
Criteria I	18	.48	.51	.51	.58	.48	.47	.45	.45	.64	.54	.50		.50	.23	.25	.21	.21			
Criteria II	19	.55	.65	.43	.61	.67	.56	.66	.69	.73	.61	.63	.50	.38	.42	.32	.50	.38	.61	.70	
Criteria III	20	.60	.67	.38	.72	.70	.51	.67	.73	.73	.62	.58	.61	.58	.54	.41	.53	.34			
Mean	21	48	44	40	50	36	56	27	28	54	20	22	72	85	11	63	172	70	21	178	
S. D.	22	13	16	14	16	14	12	7	8	14	6	7	41	36	4	21	38	20	4	43	

TABLES OF CORRELATIONS

EXHIBIT Q-I

EXPLANATION OF CORRELATIONS

The table of correlations included in this report is an attempt to show the degree of relationship existing between any two tests of night vision.

When a relationship is expressed in terms of correlation, the coefficient may vary from -1.00 to +1.00. A plus figure indicates a positive relationship, that is, the higher the score on one test, the higher the score on the related test. A minus figure indicates a negative relationship—the higher the score on one test, the lower the score on the related test. A correlation of .00 would indicate that no relation exists between the two tests correlated--that is, knowing the score obtained on one test does not make possible the prediction of a score on the second test. A correlation of either +1.00 or -1.00 indicates the highest degree of relationship between any two tests. If two tests correlate +1.00, (or -1.00) it is possible to predict a person's score on one test exactly from his score on the other test. Coefficients lying between .00 and +1.00 (or between .00 and -1.00) indicate varying degrees of relationship; the amount of relationship increases as the size of the correlation coefficient increases. It should be stressed that correlation coefficients are not percentages. A correlation of .80 does <u>not</u> represent an 80% degree of relationship.

Reliability is the measure of <u>how well</u> a test measures what it is supposed to measure; that is, it is a measure of how typical an individual's score is of his performance on that test. In the field of testing, a test is generally thought to be reliable enough for individual diagnosis if the correlation coefficient is .90 or above. Tests with reliabilities of .80 or above are considered reliable enough for use with groups. Tests with reliability coefficients below these figures are considered too unreliable for use in classification.

Validity may be defined as whether a test measures <u>what</u> it is supposed to measure. The usual method of establishing the validity of a test is to correlate the test with a criterion. The criterion is generally a known measure of the performance that is being predicted. If possible, the criterion should be a sample of the actual job to be performed. If this is not possible, a rating of the performance or a quantitative measurement of some aspects of the job should be made. When the validity correlation of a test is less than .40, the predictive value of the test is dubious. When the validity of a test is more than .40, the test is a useful predictor. The higher the correlation coefficient, the greater the predictive value of the test.

EXHIBIT Q-2

split-half reliabilities have been computed for 40-trial tests, and the reliability of 80-trial tests predicted by the Spearman-Brown attenuation formula. The predicted reliability is probably slightly higher than the true reliability of the tests.

(b) It is generally accepted that the reliability coefficient of a testing instrument adequate for individual diagnosis should be at least .90. The 80-trial NV tests meet this standard of reliability, but the reliability coefficients for the 40-trial series run between .80 and .87, which is slightly below the minimum required for individual diagnosis.

(c) The split-half reliabilities were computed on the scores of the experimental group. To find out the effect of administration of the test by inexperienced personnel, the test was administered to 770 men by organization personnel. The split-half reliability obtained was compared with that for the same test administered by research personnel. The difference in reliability was negligible; the test is reliable even when administered by inexperienced personnel.

(d) The complete list of split-half and first-trial vs. second-trial correlations are found in Exhibit R.

(e) The reliability correlations obtained when the tests were later administered to the experimental group are probably higher than the reliabilities of these tests upon first administration because adaptation to the test was eliminated and the proper use of off-center vision increased.

(2) First-Trial vs. Second-Trial Reliabilities.—

(a) The correlations between first and second trial scores ran slightly lower than the split-half correlations. This difference can be attributed chiefly to differential rates of learning and of dark adaptation among the personnel tested.

(b) In all NV tests, where two series of 40 presentations were separated by a break, it was found that the average score on the second series was from 2 to 4 points higher than that on the first series. This rise in score may be attributed to several factors:

1. Learning factors, including operation of indicator set-up, use of off-center vision, and general familiarity with test procedure.

2. Further slight increase in dark adaptation after the thirty-minute dark adaptation period.

3. Increased motivation on second trial through spirit of competition among men being tested. Since scores were given to the men at the end of the first series, the men may have tried to excel each other on the second trial.

TABLE OF RELIABILITIES

Tests	Number of Cases	Split-Half		First Trial vs. Second Trial
		40 Trials	80 Trials	
NVX 1	100	.85	.92	.83
NVX 2	312	.85	.92	.82
NVX 4	70	.93	.97	.92
NVX 13	98	.90	.95	.87
NVT 15*	709	.82	.90	.74
NVX 16	71	.90	.95	.86

*This reliability was based on tests administered by organization personnel--the field test of NVT 15.

EXHIBIT R

(3) Test-Retest Series.--

(a) One group of 99 men was tested with NVX 13 and retested approximately three days later to determine the test-retest reliability of this test. The men were given a 40-presentation test each time. The reliability coefficient was computed from this and then predicted for an 80-presentation test. The reliability coefficient, using this method, was a .88, slightly below that obtained by using a split-half technique on two series of 40 trials taken a minute apart.

(b) No adequate test-retest data was available on the outdoor series, but TC 44 was administered twice to the experimental group. Although the data makes direct comparison of the two administrations difficult because of differences in method of administration, place of administration, and amount of lighting available each time, a rough indication of the reliability of the outdoor tests can be obtained. The test-retest reliability coefficient was only .16. Admitting the differences existing between the two administrations of the test, it is difficult to believe that the reliability of this test would be satisfactory even under controlled conditions.

c. Distribution of Scores.--

(1) Skewness of Scores on Original Testing of Experimental Group.

(a) The experimental group's scores, using the five-class system of grouping with class I being the highest 10%, class II the next 20%, class III the middle 40%, class IV the next 20%, and class V the lowest 10%, manifested a marked piling up in classes II and V. This piling up might be attributed to

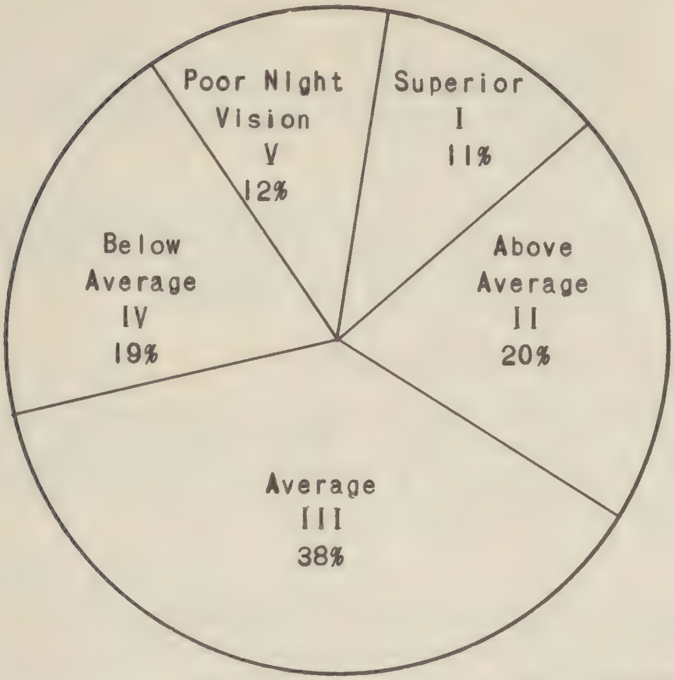
<u>1</u>. Many men in class II on first testing might have moved to class I with a little practice and training in night vision. They were in class II because they had not learned to make their night vision most effective.

<u>2</u>. The piling up in class V may have been due to lack of knowledge of how to operate the test devices. This is doubtful, however, since the same trend continued throughout the testing period, during which time the experimental group was retested repeatedly.

<u>3</u>. Since there were only 100 cases in the experimental group, it may be completely unrepresentative of the total population. When 770 cases from another organization were tested, this piling up in class V was not manifested.

<u>4</u>. The distribution of the scores in the grouping system is shown in Exhibit S-1. The diagram illustrating the breakdown by classes on an 80-trial test was taken from the scores of the field test. The actual classifications run very close to the percentages predicted for each class. The scores thus approximate a normal distribution.

80 Trials - NVT 15
401st. G. P.
N = 706



Cl.	Rating	N.	%
I	Superior	78	11%
II	Above Average	141	20%
III	Average	268	38%
IV	Below Average	134	19%
V	Poor Night Vision	85	12%
Total		706	100%

DISTRIBUTION OF SCORES (BY CLASSES) NVT 15

80 TRIALS

EXHIBIT S-1

5. The distribution of the scores of the group described in the paragraph above on the first series of forty trials is illustrated in Exhibit S-2. The upper circle shows the breakdown of class V before retests. The lower circle shows the breakdown by classes after class V had been retested and reclassified. The percentages differ much more from the predicted percentages than do the percentages obtained on the 80-trial test.

6. In the light of the previous two paragraphs an 80-presentation test seems to give much more desirable results than a 40-trial test. For purposes of grouping, the 80-trial test is worth the extra time required.

(2) Means and Standard Deviations.--

(a) The means on nearly every test were almost in the middle of the total number possible. This was achieved by shifting the levels of light to give a proper range on either side. From this standpoint the levels of light used were ideal with whatever test character was employed.

(b) The scatter of the cases was identical on nearly every test. The standard deviations ran approximately one-third of the size of the mean; thus nearly all cases were encompassed within six standard deviations. The grouping system was based on the area lying within a specified number of standard deviations on either side of the mean.

(3) General Scatter of Scores.--

(a) The graph, Exhibit T, gives an idea of the spread of scores on the NVT 15. The scores of 709 men tested under standard conditions approximate a normal distribution curve.

(b) The scores of the experimental group, when compared with those obtained on larger groups, show the piling up described in paragraph (1) (a) above. The larger groups, because of better sampling and larger number of cases involved, fail to show this type of piling up.

d. Validity.--

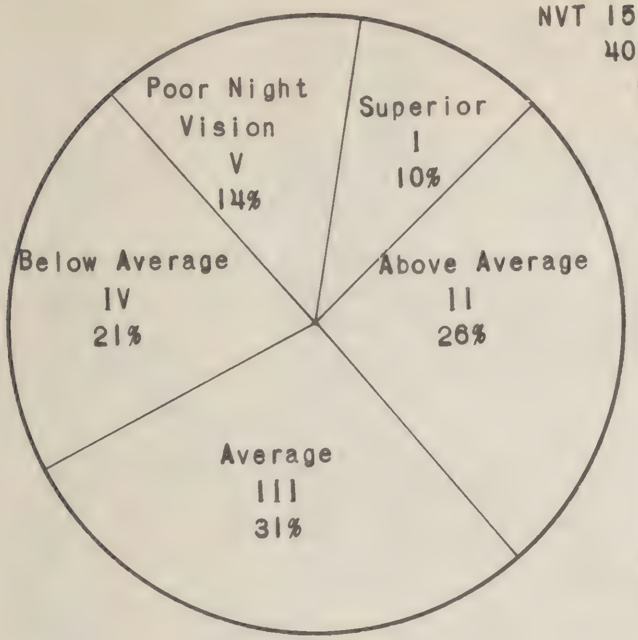
(1) Type of Criteria Used.--

(a) The criteria used for validation of the indoor tests consisted of two tests which duplicated as nearly as possible the conditions which will be found in the field at night. These tests and the reason for them have been described in detail previously in paragraphs 17, 18, and 19.

(b) A second type of criterion which might have been used is the intercorrelations among the various tests. Validation on this basis assumes that when a battery of tests to measure the same trait is given, the test which most highly correlates with all the others is the most valid because it comes closest to representing the average of all the other tests and supposedly

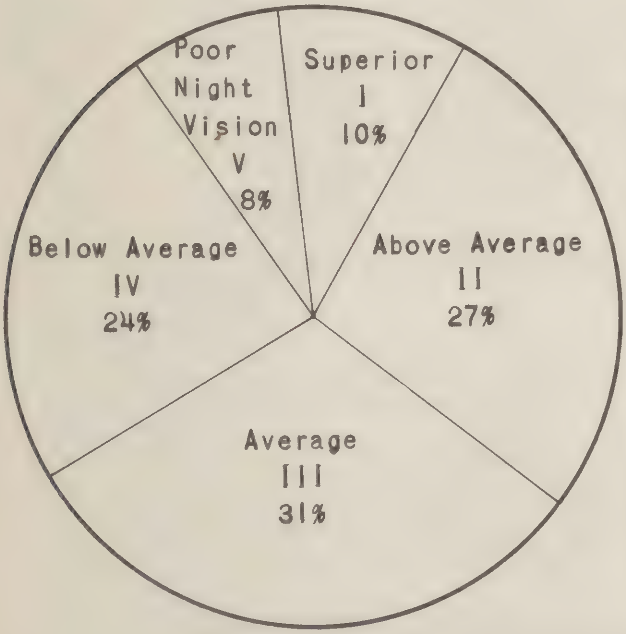
Classification on first 40 Trials

NVT 15
401 G. P.
N = 706



Cl.	Rating	N.	%
I	Superior	71	10%
II	Above Average	183	26%
III	Average	205	29%
IV	Below Average	148	21%
V	Poor Night Vision	99	14%
Tot.		706	100%

Classification on 40 Trials after Class V
had been Retested

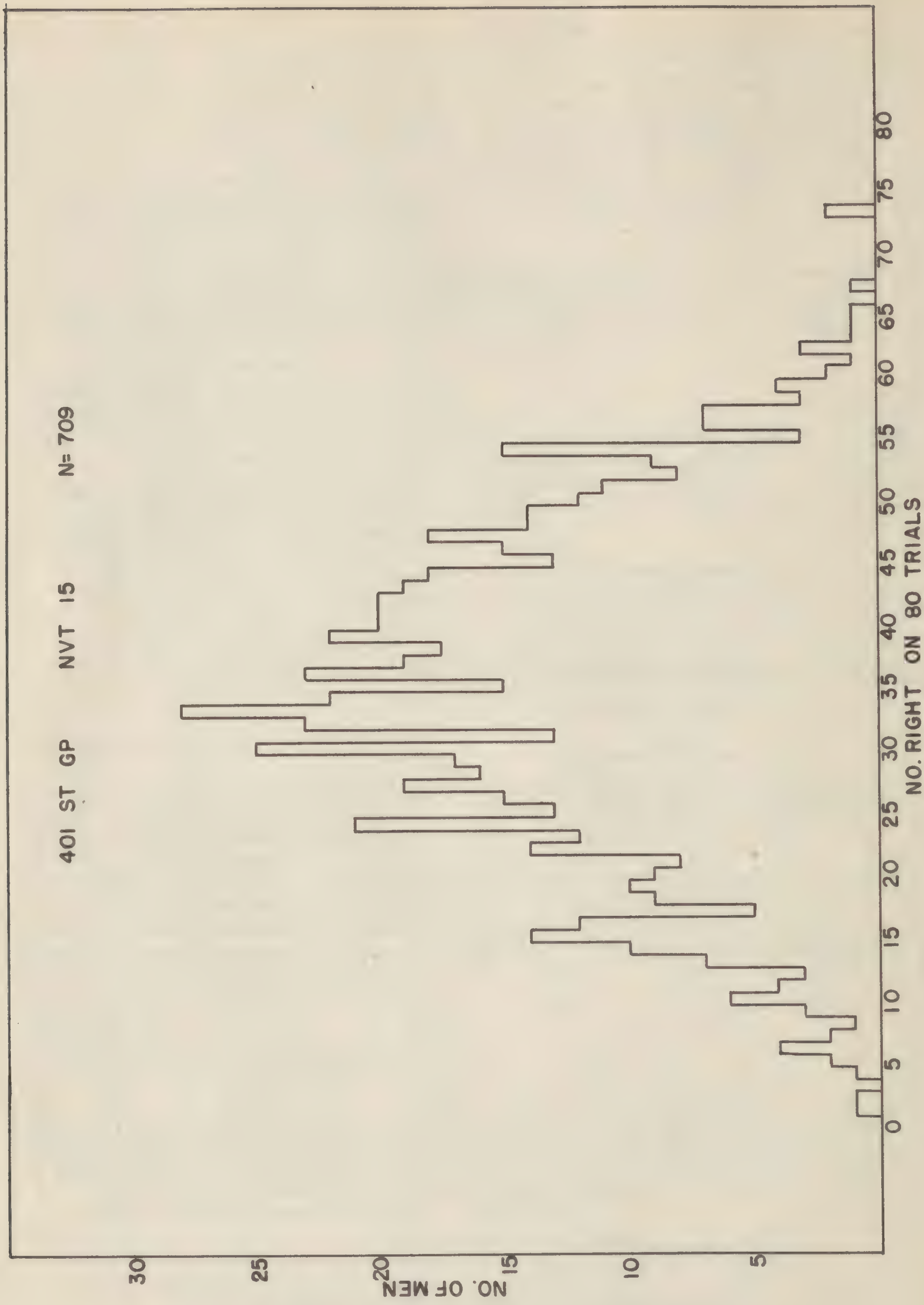


Cl.	Rating	N.	%
I	Superior	71	10%
II	Above Average	191	27%
III	Average	219	31%
IV	Below Average	169	24%
V	Poor Night Vision	56	8%
Tot.		706	100%

DISTRIBUTION OF SCORES (BY CLASSES) NVT 15

40 TRIALS

EXHIBIT S-2



DISTRIBUTION OF SCORES

EXHIBIT T

measures more common factors of the ability than any one of the other tests. (See Exhibit U.)

(c) On the basis of the outdoor tests, used as validity criteria, NVX 2, NVX 4, NVX 13, NVT 14, and NVT 15 possessed almost equal validity.

(d) Tests NVX 3, NVX 16, Feldman Adaptometer, Luckiesh-Moss, TC 44-1, TC 44-2, and TC 44-Z were definitely inferior to the tests listed in paragraph (c).

(e) The NVX-1, Film-Strip, and Packing-Box Tests are intermediate between the tests of paragraph (c) and (d) above. In view of the need for simple group tests, it seems obvious that the latter two tests should be investigated further with a view to increasing their validities.

(f) There is insufficient data on NVX 5, NVX 6, NVX 7, NVX 8, NVX 10, NVT R1, and NVT R2 to determine the validity coefficients for these tests. However, the high correlations of NVX 5, NVX 7, and NVT R2 with tests having high validity correlations would suggest that these tests may be of equal validity with the tests listed in paragraph (c).

(g) The pad-and-pencil test was identical with NVX 13 except for the scoring system used. The field test (401st Group) was identical with NVT 15, and the accelerated-time test was identical with NVX 2 except for the timing. Therefore, it can be assumed that these tests have validity equal to that of the tests they resemble.

(h) Although the validity coefficients for the tests of paragraphs (c) and (e) are much higher than any previously recorded in other studies and furnish evidence that both the tests and the criteria are probably superior to those developed by other investigators, it must be borne in mind that the number of cases from which these figures were obtained were too small to justify too sweeping conclusions. Further validation work should be done.

e. Effect of Test Character on Scores.--

(1) Size.—

(a) To give scores comparable to those obtained on the 2° Landolt ring, the 1° Landolt ring requires levels of light one or two log units higher. This is in line with the cardinal principle that night vision is dependent upon size and contrast. As the size increases, the amount of contrast necessary to see an object decreases; when the size decreases, the amount of contrast must be increased if the object is to be seen.

(b) The large T required a very low amount of contrast to be perceived as compared with the ordinary airplane figure (2°), or the Landolt rings, either 1° or 2°. This is in line with paragraph (a).

TABLE OF INTERCORRELATIONS OF NIGHT VISION TESTS

"A" BATTERY - 694th FIELD ARTILLERY BATTALION

	NVX 1	NVX 2	NVX 4	NVX 13	NVX 14	NVX 15	LARGE T
NVX 1		83 / +.76	40 / +.74	65 / +.70	70 / +.71	57 / +.75	53 / +.46
NVX 2	83 / +.76		47 / +.88	70 / +.80	71 / +.77	60 / +.87	56 / +.69
NVX 4	40 / +.74	47 / +.88		43 / +.80	47 / +.86	37 / +.83	36 / +.82
NVX 13	65 / +.70	70 / +.80	43 / +.80		59 / +.85	48 / +.85	48 / +.67
NVX 14	70 / +.71	71 / +.77	47 / +.86	59 / +.85		57 / +.88	56 / +.80
NVX 15	57 / +.75	60 / +.87	37 / +.83	48 / +.85	57 / +.88		49 / +.75
LARGE T	53 / +.46	56 / +.69	36 / +.82	48 / +.67	56 / +.80	49 / +.75	

NOTE: 1. Numbers above diagonal are number of cases used.
2. Numbers below diagonal are correlations.

EXHIBIT U

(c) With the increase in size of the test figure from 1° to 2°, the correlations with the criteria increase. However, when the figure is increased to large T, the correlations of the test with the criteria fall. It may be deduced that the 2° Landolt ring and the airplane figures are nearest to proper size if the test object is to produce desired visual acuity "load."

(2) Shape.--

(a) If an airplane figure is used, visibility is increased when the cross arm is moved closer to one end. The closer the airplane approximates a T figure, the more easily it is seen. The nearer the cross arm approaches the center of the body, the finer the discrimination the examinee must make, for he must determine which end of the body is the longer and decide on the orientation of the airplane on this basis.

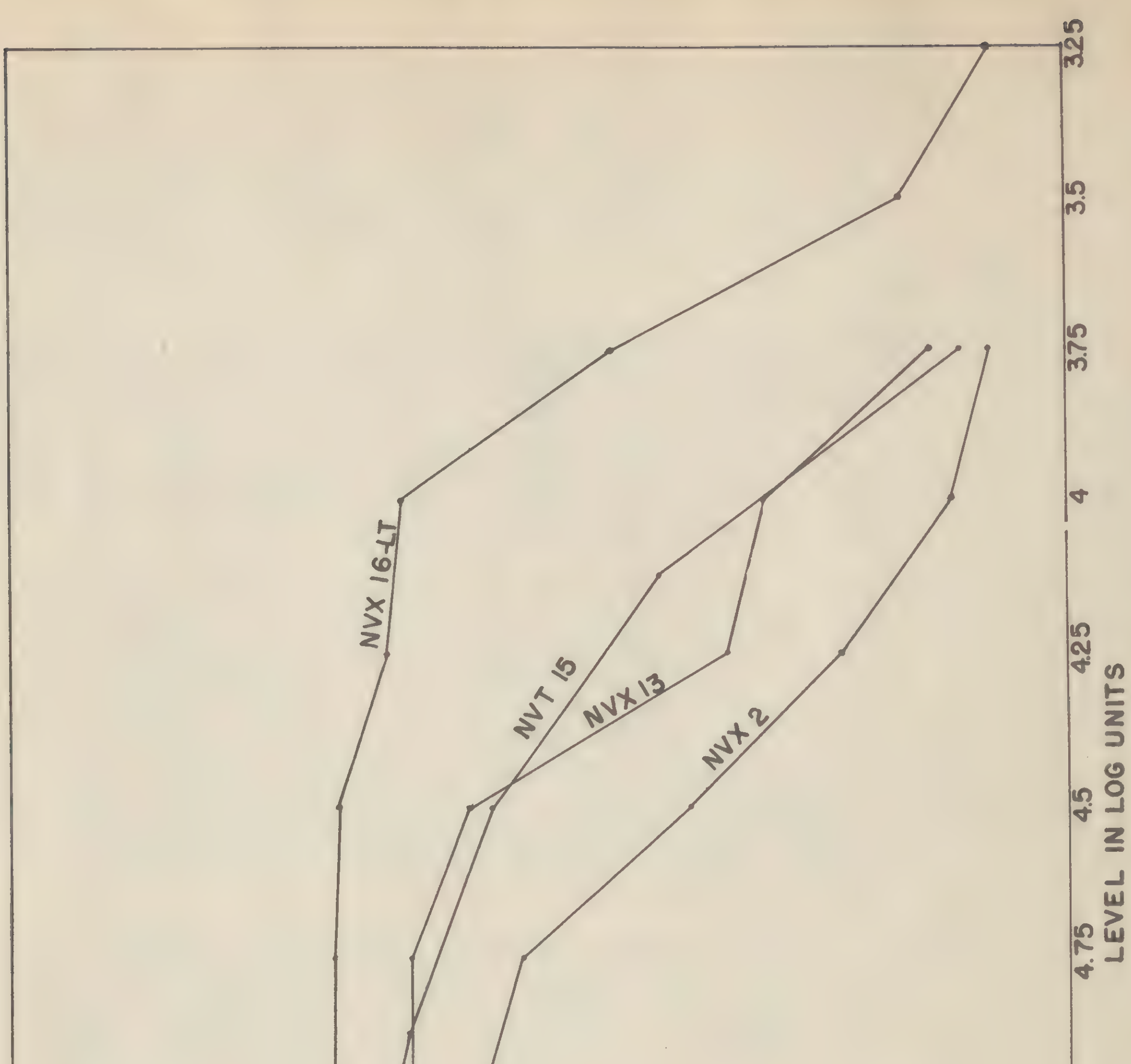
(b) When a 2° Landolt ring was compared with a 2° airplane figure, the airplane figure was seen more easily. This may be attributed to the fact that once the subject can see the long body of the airplane, he already has the direction localized in one of two positions, and it is then a matter of judging the location of the wings. Toward the end of test, when the wings of the plane become difficult or impossible to see, his chance of guessing is increased. It is unfortunate that, during latter part of the test, the scoring method used did not provide accurate identification of direction of body vertically, horizontally, or diagonally.

(c) The airplane figure seems to differentiate somewhat differently from the Landolt ring; it causes two breaks in the scoring rather than one. In the NVX 13 test, the level-by-level curve is somewhat characteristic of tests with Landolt ring until the fourth level--the break in visual acuity is between third and fourth levels. However, the curve reverses between the fourth and sixth levels, suggesting that contrast sensitivity predominantly is being measured. The similarity of the airplane body with the TC 44 test bar can account for the relatively high correlation of this test with the TC 44 tests.

(3) Cut-out vs. Silhouette.-- There did not seem to be any appreciable difference between using a silhouette target or a cut-out target during testing. The only difference between the two is in the size of the test character that can be utilized. It is much easier to construct a box with a large cut-out target than one with a silhouette target of equal size.

f. Effect of Levels of Light Used.--

(1) On the basis of careful level analysis of the scores obtained on all NV tests, it was found that certain levels of light were much more discriminating than other levels. (See chart, Exhibit V). The particular levels involved depended upon the type of test character used. The larger the test character and the more easily seen, the lower the discriminating levels of light.



LEVEL ANALYSIS - AVERAGE NO. RIGHT AT EACH LEVEL ON

NVX 2, NVX 13, NVT 15, NVX 16

EXHIBIT V

(2) On the first levels on every test the scores showed little variation from level to level. However, all tests showed a sharp break in a two or three step area where the scores differed markedly from level to level.

(3) The top levels differentiated the best men from the worst but were of little use in differentiating among the average men.

(4) The bottom level did not serve to differentiate between the best and poorest men. Scores at this level were, in nearly every case, purely chance scores.

(5) On the basis of these findings it was suggested that it might be valuable to give more trials over the critical area. This was tried on NVX 7; the results tended to show that scores obtained in this manner were at least as valid as scores obtained over an eight-level range. Some individuals, however, claimed they were not sufficiently dark adapted to start at the critical levels. Thus, the higher levels may serve a practical purpose in bringing the examinees gradually into the critical range. It is difficult, however, to see what purpose the lowest level serves. Further work on level analysis and breakdown of levels of light within the critical area should be carried on.

g. Fixation Light.--

(1) The fixation light was used to aid the subjects in localizing the test object. The results on these tests were generally negative. However, since the fixation light required the subjects to fixate at one point, and thus eliminated scanning, it may have resulted in a loss of sensitivity in the area of the eye where the light from the viewing screen fell. Two lights on either side of the viewer, between which the examinees could have scanned, might have been of more value.

(2) In NVX 4, where subjects had a <u>choice</u> of using the fixation light or not, the results were good.

h. Effect of Timing on Test.--

(1) Two tests were run on the effect of timing on the test scores. On one test a five-second exposure period was used with a ten-second period between exposures. The results on this test were of dubious value. Only a small number of men took this particular test; if it had repeated with larger numbers, satisfactory results might have been obtained. The second test utilized a seven-second exposure period with eight seconds between exposures. The results on this test were generally favorable, and in all probability a timing sequence of seven and eight seconds can be used.

(2) Using a timing sequence of seven and eight seconds, the 80-trial test is approximately 7 minutes shorter than the other NV tests on which the timing of ten and ten seconds was used.

i. 4° Field vs. 6° Field.— A 4° field was used on every NV test except NVT 14L and NVT FS where a 6° field was used. Comparison of scores obtained on a 4° and a 6° field show little difference. For all practical purposes there is no difference between a 4° and 6° field.

j. Role of Chance in NV Scores.--

(1) If a man is totally night blind and incapable of seeing a single presentation on a 40-trial test, he has about one chance in 25,000 of getting a score high enough on NVT 15 to move him out of class V (poorest) into class IV (below average). The chance of moving into class III (average) is one in several millions.

(2) On an 80-presentation test, a truly night-blind person has only one chance in 100,000,000 of correctly guessing enough presentations on NVT 15 to move into class IV. The chances of moving into class III are infinitesimal. A person who is capable of seeing only the first level has one chance in 5,700 of correctly guessing enough more presentations to move into class IV. The chances of this person moving into class III are also infinitesimal.

(3) Conclusion.-- It is extremely improbable that chance plays any noticeable role in the scoring of the NV series. Although chance may increase a man's score a point or two, it is not sufficient to move him out of his original group. The chances of a truly inferior person receiving too high a score because of chance factors are extremely small.

k. Shifts in Group from One Series to the Second Series.--

(1) In the NVX and NVT tests, scores of individuals varied as much as a full group from one series to another; much more rarely, as much as two groups. This is due, not to the test device, but to certain human factors. Physical conditions, interest or motivation, attention, training, and comfort are such factors.

(2) The U. S. Naval Medical Research Institute recently reported that there is, in all dark-adaptation thresholds below the highest levels, a wave-like fluctuation, with a 3 to 7-minute period and an irregular amplitude from 0.05 to 0.25 log units of test brightness. The existence of these fluctuations makes exact treatment difficult, but its effect may be offset if the test is of sufficient length.

(3) A critical test will mirror these various factors, and it is believed that the FAS NV Test is sufficiently sensitive to do this.

l. Feldman Tests.—

(1) To bring the Feldman test within the range of rod adaptation rather than mixed cone and rod adaptation as it is in the original test, the levels of the preadaptation and test lights were reduced as previously explained.

(2) Lack of time, caused by inability to replace a burned-out part, did not permit as complete a study with the Feldman Adaptometer as had

been planned. Cases tested were too few, and no safe conclusions could be drawn from the results. However, there is little, if any, difference existing between scores obtained using a three, four, or five minute pre-exposure period. Enough light adaptation occurs after three minutes; little change is manifested during the remaining two minutes of exposure. The time taken to dark adapt to the level of the test light (bar) is the same regardless of the length of pre-exposure beyond three minutes, provided the pre-adaptation brightness level remains constant.

(3) It should be pointed out that while the Feldman Adaptometer is not a satisfactory test for the broad grouping purposes we desire, it does screen out the very poorest or night-blind persons from the rest. This is the purpose for which it was designed.

m. Luckiesh-Moss Chart.--

(1) Scoring Difficulties.--

(a) It was extremely difficult to grade the Luckiesh-Moss Test Chart. Many subjects missed three or four figures in a row and then read correctly the next several figures. Several types of scoring systems were discussed; among them

1. Counting the number of figures read correctly.

2. Counting the number of figures read correctly, and subtracting one for each figure read incorrectly.

3. Giving the subject the score of the last line in which he read both figures correctly.

4. Weighting the figures with regard to the degree of contrast and scoring the individuals with this weighted scoring system.

(b) None of the above systems seemed entirely satisfactory but the number of figures read correctly was used.

(2) Conclusions.--

(a) The correlation of this test with the criteria was low; this test cannot be recommended.

(b) Administration of this test requires much time; it is not suited to mass testing.

n. Single-Level vs. Multi-Level Tests.-- Level-by-level analysis of our tests indicates that no test at one level of night brightness is sufficiently predictive to warrant adoption. A test of at least three or perhaps four levels is indicated to be the best.

o. Effect of Variations in Test Details.—

(1) The trend of the tests indicates that regardless of the way the tests are given--fixation versus no fixation, large versus small test object, higher initial brightness levels versus lower brightness levels, etc.--the scores of the experimental group tend to be relatively the same.

(2) This is satisfactory because it means that minor variations caused by less well controlled conditions in the field should not materially affect the results of the field model, particularly if an entire group is tested with the same test set-up.

p. Miscellaneous Results.—

(1) White vs. Negro Scores.— Virtually no difference was found between the test scores of 75 negroes and those of 175 whites either with regard to average scores or to the scatter of scores.

(2) Officers vs. Enlisted men.— No difference was found between the scores of officers and enlisted men. This was true both with regard to average scores and to the scatter of scores.

(3) Effect of Age.— There is a trend toward poor night vision with increasing age.

(4) AGCT Scores.— The correlation between Army General Classification Test scores and scores from the night vision test is exceedingly low.

(5) Country vs. City.— Contrary to the theory that farm boys and hunters might be better observers, no relation was found to exist between an individual's night vision score and his civilian residence or occupation.

(6) Personal Opinion as to Visual Abilities at Night.— An individual's personal opinion as to how well he could see in the dark cannot be relied upon.

(7) Cooperation.— Cooperation was generally very good throughout the study, probably because the reasons for need of best efforts at all times were thoroughly explained to the examinees.

(8) Rough Screening by Tests.— It is indicated that any measurable task entirely at rod levels of illumination can serve as a rough means of screening out the completely night blind or those with the poorest night vision. Hence, it is probable that the Feldman Adaptometer, the Luckiesh-Moss Test Chart, the Radium Plaque Adaptometer, and other similar tests do function to screen out night-blind individuals when used under constant, standard conditions.

(9) Day Vision vs. Night Vision.— There is no correlation between day vision and night vision.

24. CALIBRATION BY THRESHOLD LEVELS OF COLOR PERCEPTION.--

a. Although the NVT test devices when constructed and utilized as directed are practically self-calibrated, a simple means of calibration for check purposes would be of value.

b. It appeared possible to use the threshold levels for color perception, provided they prove to be within a narrow range for the average of individuals.

c. Texts assert that night vision is colorless vision; therefore a rough borderline between cone and rod vision should be the narrow zone of brightness levels where perception of color ceases and color appears only as a shade of gray.

d. On this assumption, some limited experimental work was attempted. Because equal-brightness color cards and other necessary items were not available, this part of the general study was never concluded.

e. The limited experimental work did give a positive indication that color perception is possible at much lower brightness levels than reported in the literature. Continuation elsewhere along these lines might prove fruitful.

25. CONTRAST SENSITIVITY VERSUS VISUAL ACUITY.--

a. Work of Luckiesh and others has indicated that, at the low levels of night illumination, the factor of contrast sensitivity is a factor in night vision as important as, or more important than, visual acuity. Research at the Lighting Research Laboratory of the General Electric Company has shown that a group of subjects having the same visual acuity will show a range of contrast sensitivity of more than two to one.

b. Some amount of visual acuity as well as contrast sensitivity is needed to see in military operations at night. In night driving, in the ability to distinguish between the road and the side of the road, contrast sensitivity is the prime consideration; however, to recognize military objects and personnel visual acuity is necessary.

c. There is indication that the NVT tests measure both factors about equally well. If the scores for these tests are correlated with the initial perception distances obtained in Observation Test II and these correlations compared with the correlations for recognition distances, the correlations are approximately equal, as can be seen from the following:

Observation Test II

Test	Perception Distance	Recognition Distance
NVX 2	.65	.70
NVX 13	.67	.65
NVT 15	.73	.71
NVX 16 (Large T)	.56	.53

26. NIGHT VISION AT EXTREMELY LOW LEVELS.--

a. At very low levels of night illumination, even individuals with superior vision have difficulty in perception or are unable to see at all.

b. During a trial run of Observation Test I, certain of the test staff were stationed motionless directly along the test course in a very dense portion of the woods where illumination was the lowest. Even those with the best night vision found it impossible to locate these motionless human targets. Indeed, subjects unknowingly brushed against some of these individuals.

c. Under conditions of very low illumination as in jungles at night, means other than human night vision will be necessary in order to perceive or recognize enemy personnel and objects.

d. The indicated solutions are mechanical, electrical, and electronic-radiation detection devices. Since considerable developmental work has already been done along this line, future study of night vision should include consideration of all possible wider applications and improvements.

27. DISCUSSION OF SELF-ILLUMINATED RADIUM-ACTIVATED MATERIAL.--

a. The advantage of a self-illuminated, constant-value light source for a night vision tester is obvious. Any incandescent lamp source and its necessary electrical and wiring system is relatively complicated and likely to contribute sources of error. The Navy, the National Defense Research Committee and the Army Air Forces are making use of self-illuminated radium-activated plaques in their night vision adaptometers for individual testing. Its use, however, in a multi-level, mass night vision tester poses mechanical problems. The radium plaque adaptometers of the NDRC and the Navy, which employ filters mounted on shutters, have not proved mechanically satisfactory thus far.

b. At first, the use of standard radium-activated buttons and plaques already in production was attempted. It was found impossible to use these. The buttons caused "hot spots" in the screen, and the existing plaques were insufficient in area or in intensity. It is true that a series of large-sized plaques of varying intensities could be employed but the great expense would be unwarranted.

c. In cooperation with the United States Radium Corporation of New York, a special self-illuminated radium-activated light source was developed. It seems to be a simple and adequate solution for the required purpose and consists essentially of a relatively low-intensity radium-activated mixture or compound deposited on a heavy cardboard material by means of a clear binder or adhesive. A square of this material, 10" by 10", functioned very well in the NVT R2 Model previously described (Exhibit G-3)*. On the basis of data for similar radium-activated materials, it should emit constant light for a long period without noticeable decay.

d. Since there is a substantial rise in brightness in all three radium-activated materials when exposed to light, measurements were taken with the Taylor Low-Brightness Meter after this new material had been exposed for ten minutes to bright sunlight and then taken into a dark room. Fading was noted only during the first half hour. Thereafter, no appreciable change in brightness could be measured. This means that accidental pre-exposure to light need not be feared as with other adaptometers using similar material of higher-intensity radiation. The measurements were as follows:

* p. 25

TIME AFTER EXPOSURE	AREA EXPOSED 100 sq. in.	AREA EXPOSED 40 sq. in.	AREA EXPOSED 4.5 sq. in.
0 hours	.00030 ft.-lambert	.00014 ft.-lambert	.000016 ft.-lambert
1/2 hours	.00020 ft.-lambert	.000095 ft.-lambert	.000016 ft.-lambert
1 hours	.00020 ft.-lambert	.00009 ft.-lambert	.000016 ft.-lambert
2 hours	.00020 ft.-lambert	.00011 ft.-lambert	.000014 ft.-lambert
4 hours	.00020 ft.-lambert	.0001 ft.-lambert	.000016 ft.-lambert
5-1/2 hours	.00021 ft.-lambert	.00012 ft.-lambert	.000017 ft.-lambert

Variations after one-half hour are probably due to the human error in readings.

28. FILM STRIP AS MEANS OF TEST PRESENTATION.--

a. Presenting the night vision test in film-strip form using the standard film-strip projector with some minor modifications offers definite advantages if the production of such a film strip proves practicable. Test NVT FS described in paragraph 14 indicates the feasibility of the film strip method.

b. Film-strip projectors are said to be available for nearly all field units. Film strips and a necessary replacement of lamp bulb would not be bulky items and could be shipped everywhere without difficulty.

c. In December a member of the research staff spent several days in the film-strip printing laboratories of the Signal Corps Photographic Center, New York City, at which time considerable progress was made in investigating the possibilities of producing such a film strip.

d. Unquestionably certain production and other problems will be encountered in attempting to utilize the film in the field. However, the convenience and simplicity of such a method of presenting the test, if successful, warrants continued effort.

e. Meanwhile, the preferred model for immediate production and dispatch to the field is the NVT R2, some modification thereof, or the field model NVT described in Appendix II.

29. AVAILABILITY OF DARK ROOM FACILITIES FOR TESTING.--

a. The theatres, recreation halls, barracks, and other buildings where testing was to be done were checked to see whether or not these could be darkened sufficiently to provide the light levels required for the test.

b. It was found that blankets or similar means were not satisfactory for blacking out temporary buildings in the daytime. Covering windows with tar paper did provide an adequate daytime blackout. One of the satisfactory locations for tests proved to be a large attic of a barracks.

c. A resourceful organization should be able to find or improvise quarters, whether in a basement, Nissen hut, attic, or elsewhere for daytime tests, but if this fails, testing can be done in any large quarters, including large tents, if done during the night.

30. FIELD TEST OF DARKNESS OF TESTING ROOM.—

a. Since organizations in the field will not have photometric devices for the measurement of light intensities in the adaptation and testing rooms, some practical means of measuring these intensities must be devised. The following method can be used. Although not as fine as the measurements afforded by photometric devices, it will serve all practical purposes.

(1) Select ten individuals from the organization to be tested to be used as a "jury." These individuals are to be dark adapted for thirty minutes in the test room.

(2) At the completion of the dark-adaptation period the examiner, standing by the viewer (with all lights off), will tap the viewer with a pencil to indicate the general direction of the screen.

(3) Each member of the "jury" will indicate whether or not he can see the screen. The members of the jury may be given numbers before entering the room, and they will report in order of their numbers. Jury should be at testing distance from screen.

(4) If some members report they can see the screen, the examiner will test each one in turn by alternately standing in front of the screen and stepping away, asking the member being tested each time whether he can still see the screen.

(5) If more than one member of the jury can really see the viewing screen with all lights off, the room is too light and should be further darkened. If this is impossible, testing should be carried on only at night.

31. MISCELLANEOUS TESTING CONSIDERATIONS.—

a. Need for Retest.—

(1) Studies of recent literature and battlefront reports indicate that troops that have been in combat, particularly in the tropics, must be tested for night vision at least once every six months.

(2) The eyes of antiaircraft gunners are particularly susceptible to damage because of the necessity of looking into the sun in combat.

(3) Prolonged exposure to the glare of the tropical sun is known to damage permanently the rods of the eyes without the knowledge of the individual.

(4) Prolonged abnormal diet for long periods of combat duty or for other reasons may temporarily impair the night vision ability of individuals.

b. Tests of Materials.--

(1) Test of Reliability of Storage Batteries.--

(a) In order to learn if current from a storage battery source was steady and reliable, three used vehicular batteries, taken at random, were tested.

(b) Before the test they were fully charged, then different loads were put on each ranging from 3 to 21 candlepower. Readings were taken hourly all day. Batteries were disconnected during the night.

(c) Results were entirely satisfactory. With the heaviest probable load for NVT purposes, the average storage battery should furnish steady current for 4 to 8 days before requiring recharging.

(2) Tests of Screen Materials.-- By far, the best screen for trans-illumination is common white tracing cloth. For simple systems, it was superior to opal glass, tracing paper, sand-blasted cellulose acetate, and other materials.

(3) Test of NVT Lamp Bulbs.--

(a) It was desired to ascertain the variations in brightnesses that might be expected of the 3-candlepower 6-8 volt bulbs used in the NVT.

(b) Sixty bulbs were drawn from several supply sources and tested. They were inserted in the modified receptacle of the NVT FS, previously described in paragraph 14d, and burned in turn at 3.6 and 5 volts; and their light was thrown on a white cardboard screen at a fixed distance. Readings were taken with the Taylor Low Brightness Meter and are shown in the table in Exhibit W.

(c) Variations were small. Human error in reading can account for part. Where lamps are used three at a time, as they are, these minor variations should tend to average out in a majority of cases.

c. Comments on Outdoor Experience.--

(1) Even a person with much outdoor experience at night probably does not appreciate the tremendous differences that exist between the appearance of objects in the daytime and at night and the tremendous changes that may occur even from moment to moment in night illumination. For example, in a preliminary trial of Observation Test II in half moonlight, the brightness of the sky changed 100% when a few wisps of clouds passed over the moon. At the same time, the brightness reflected from trees and objects on the ground changed as much as 1000%. (See Table of Illuminations).

(2) Even on moonlight nights, identification of common objects is unbelievably difficult. During the validation studies, a 155-mm howitzer standing in the open, but against the background of a large tree, could not be identified by members of the experimental

CALIBRATION OF SAMPLE LAMPS

Table of brightness of 60 three-candlepower automobile bulbs operated at 3.6 volts and 5 volts. Tests made by projection through SVE 5-inch focal length projector on white cardboard screen. Measurements in foot-lamberts, by Taylor Low Brightness Meter.

Test date: 5 January 1944.
Lamp bulbs were random selection.

Bulb No.	3.6 Volts	5.0 Volts*	Bulb No.	3.6 Volts	5.0 Volts*
1	.0021	.0022	31	.0026	.0016
2	.0022	.0019	32	.0027	.0017
3	.0024	.0022	33	.0019	.0018
4	.0021	.0019	34	.0018	.0016
5	.0023	.0019	35	.0021	.0019
6	.0018	.0019	36	.0021	.0018
7	.0019	.0019	37	.0020	.0017
8	.0020	.0019	38	.0019	.0016**
9	.0020	.0019	39	.0018	.0016**
10	.0020	.0019	40	.0019	.0017
11	.0021	.0019	41	.0020	.0017
12	.0025	.0018	42	.0022	.0018
13	.0022	.0020	43	.0020	.0018
14	.0022	.0017**	44	.0020	.0018
15	.0022	.0019	45	.0021	.0018
16	.0024	.0018	46	.0016**	.0016**
17	.0020	.0018	47	.0018	.0017
18	.0021	.0017	48	.0015**	.0016**
19	.0021	.0017	49	.0018	.0020
20	.0017	.0017	50	.0017	.0019
21	.0021	.0022	51	.0020	.0019
22	.0021	.0019	52	.0018	.0019
23	.0019	.0019	53	.0017	.0016
24	.0021	.0019	54	.0020	.0022
25	.0018	.0019	55	.0019	.0018
26	.0023	.0018	56	.0018	.0016
27	.0023	.0021	57	.0019	.0018
28	.0021	.0018	58	.0020	.0018
29	.0021	.0018	59	.0019	.0018
30	.0020	.0022	60	.0019	.0018

*Filter used in projector.
**Filament off-center (reversing bulb generally raised reading).

EXHIBIT W

group when their average distance from the howitzer was more than 31 yards. When the moon was obscured some individuals had to come close enough to feel the howitzer before identification could be made. A four-ton prime mover whose silhouette was particularly obscured by a tree trunk was identified as a wheelbarrow covered by a fish net. A half-track, in the open but silhouetted against a nearby tree and a tree line at a greater distance, could not be identified except at a very close distance. One individual identified it as a row-boat.

(3) Even in starlight, shadows cast by objects greatly hinder identification although they may occasionally aid it.

(4) The standard OD paint on weapons and vehicles blends extremely well with the background. In bright half-moonlight, the contrast between the shield of the 155-mm howitzer and a tree background was 30%. When the moon was obscured, the contrast dropped tremendously.

d. Use of Red Light.— Deep red lights at lowest practicable intensities have been found the best illumination for maintaining the dark-adapted state.

e. Field Manuals.— Careful search was made of the contents of War Department Field and Technical Manuals for references to night vision and night vision training. Although some mention is made of night observation, such information is nonexistant, except in the new FM 21-75. This situation is probably being corrected in the newer manuals as they are published.

32. THE PROBLEM OF MALINGERERS.—

a. In any test which may mean undesirable or extra-hazardous duties if a high score is obtained, certain individuals will invariably malinger, or try to beat the test. A night vision test is no exception. For example, during the laboratory testing, one soldier's score was poor test after test. One day during testing the lights were unexpectedly turned on, and he was found taking a nap. After detection, this soldier's scores became and remained average. The Submarine Section of the United States Navy has expressed particular concern over the problem of malingering.

b. The chances are exceedingly small that a truly night blind person will obtain a satisfactory score on the Field Artillery School Night Vision Test, if administered as recommended. (See par. 23j.)

c. It is believed possible that a minor modification which should not interfere with normal use, can be built into the regular NVT to detect malingerers. Since the preferred procedure is to retest all soldiers with poor scores, all that seems necessary is to include in the retest several higher brightnesses which definitely stimulate daytime vision. Three 21-candlepower bulbs added to the regular bulbs, and burned at 6 volts, are found sufficient to raise the two highest levels of the NVT 15 to .025 and .012 foot-lambert of brightness. If an individual with a previously adequate Snellen rating claims he cannot see the test object at these daylight levels, it should be fairly conclusive that he is faking.

33. NIGHT VISION TRAINING.--

a. Training Improves Night Vision.-- Unquestionably, an individual's night vision ability can be improved by systematic training. Night vision training is essentially training and practice in "off-center" vision and scanning.

b. Importance of Indoctrination.-- The principles of "off-center" vision and scanning are easily grasped by most individuals, and limited repetitions of the NVX and NVT are sufficient to teach the slower individuals. In fact, the NVT or NVX is an excellent aid for teaching the principle of "off-center" vision. However, when individuals were sent to the field for night operations, there was a definite tendency to forget this principle. Hence, initial orientation and indoctrination should be so thorough that soldiers will realize that constant practice of "off-center" vision may not only save their lives but be the margin of success in battle.

c. Night Operations.-- Efficiency in night operations and in night combat is not merely a problem of night vision alone but also of training, tactics and techniques, and equipment.

d. Best Method of Training.-- The best method of training military personnel to recognize military objects such as vehicles, weapons, men, etc. in the dark is to show them these objects under conditions approximating those in night combat. The men should be instructed on the types of false devices used by the enemy, on objects that are commonly misidentified at night, and on any tricks which might be used to aid recognition and should be given as many exercises and problems under night conditions similar to those found in combat as possible.

e. Other Factors.-- There are undoubtedly a number of factors other than vision, such as intelligence and stability under stress, that must be considered when choosing and training men for night observation. Standard psychological tests should prove useful as an addition to night vision tests for the purpose of choosing observers. Other desirable abilities are

(1) Ability to estimate distances.

(2) Rapid adaptability to sudden light changes.

(3) Ability to distinguish lights of different colors.

(4) Good physical condition.

(5) Familiarity with different appearances of military objects in the dark.

(6) Good hearing.

f. Effect of Competition.-- There were indications that men can force themselves to see better if they concentrate intently on seeing, properly use scanning and "off-center" vision, and exert greater effort to see. This additional effort was stimulated by competition between individuals, constant encouragement on the part of examiners, and continued indoctrination. Citing battlefield experience as examples of the importance of what was being attempted was helpful.

g. Importance of Sound and Smell.-- Training also must take cognizance of the greatly increased importance at night of the senses of hearing and smell.

h. Navy's Training Program.-- Training in night vision is excellent in the Navy and can be used profitably as a guide for other night vision training. However, Field Artillery problems are more complicated than the Navy's or Air Forces' and its training must go further.

34. TRAINING AIDS.--

a. Proper preparation, orientation, and motivation are essential in any test for night vision. An excellent means for accomplishing these is a training film and/or film strip.

b. A number of training films about night vision already exist. A list of these films, probably incomplete, is as follows:

(1) Vision at Night - 528-549A

(2) Vision at Night - 528-591A

(3) Laying a Night Ambush - 528-581

(4) The Sergeant was a Corporal - 528-522A

(5) Reconnaissance Operations at Night - U. S. Army

(6) Marine Reconnaissance Patrol - U. S. Marine Corps Film

(7) Marine Corps Patrol - British

(8) Duties of a Lookout - British No. 528-2

(9) Night Vision (30 min.) - MN - 16f - Navy

(10) Scanning (10 min.) - MN - 16e - Navy

Other films about observation and the care of optical instruments should also be of value.

c. It should be a comparatively simple task to utilize certain parts of some of the foregoing films quickly to make effective film strips for distribution to units in the field in conjunction with an over-all night vision training program.

d. A number of scenes in the foregoing film can also serve as basic ideas for effective charts and bulletins, particularly to remind soldiers of the prime necessity for practicing "off-center" vision, properly preadapting for night duty, and adhering to the other necessary procedures for maximum efficiency in the dark.

35. NEED FOR COORDINATED ACTION.--

a. There seems to be an unbelievable amount of lost motion, duplicated effort, wasted effort, and unused information and data concerning studies of night vision and related matters.

b. At least a dozen service and governmental agencies have been conducting studies of night vision or problems connected therewith, and these for the most part are unconnected, uncorrelated, and even unknown to others. Extensive night vision research programs have been going on for some time in England, Canada, and Russia, but the information made available is meager and fragmentary.

c. Much valuable information and data which could be obtained at the fighting fronts have not been collected, except as incidental and subordinate comments of observers and in intelligence reports. It is obvious that an organized, coordinated over-all attack on the problem of night vision and night combat factors is badly needed.

d. Formation of a Night Combat Board to study all the problems relating to night operations and to develop the most efficient tactics, techniques, and instruments for night combat for all the arms of the service seems badly needed. This board, or its equivalent, could study, utilize, and coordinate everything pertaining to the subject.

36. CONCLUSIONS AS TO OUTDOOR TESTS.--

a. General.--

(1) The outdoor observation tests were given as attempts to establish criteria for determining the validity (success) of the laboratory tests.

(2) In general, the tests given under the most favorable conditions compared favorably with the laboratory tests. Each test had shortcomings, but the group as a whole can be considered as a fair set of criteria.

(3) Outdoor tests of one nature or another could be given as a method of training in the use of the eyes at night.

(4) No single outdoor test can be devised as a suitable test for night vision. All suffer from the same shortcomings:

(a) Illumination cannot be controlled.

(b) Illumination cannot be duplicated, making it necessary to retest an entire command whenever new men are added. The only comparison that can be made is between men tested on the same night, assuming that the illumination remained fairly constant throughout the duration of the test.

(c) Illumination varies from hour to hour.

(d) Very few nights out of each month are available for test purposes because of weather conditions, moon, and the like.

(e) It is difficult to get proper cooperation from the men at night, especially in cold weather.

(f) Administration is difficult.

b. Observation Test I: The results of this test compared favorably with the laboratory tests, despite dust from a windstorm and occasional distant lightning.

c. Observation Test II: This test was the best of the various outdoor tests. The grouping of personnel tested compared very favorably with the grouping of the same men tested in the laboratory. It was given on an ideal night; undoubtedly this aided in the favorable results.

d. TC 44:

(1) This test must be considered unsuccessful because of the objections that can be raised against all outdoor night tests. Large numbers of men show marked changes in score from one such test to another. In addition to the objections listed above, TC 44 is unsatisfactory because

(a) Lack of control of surrounding contrast (earth, sky, background, etc.).

(b) There is a 25% chance of a correct guess.

37. CONCLUSIONS.--

a. With much of modern warfare waged at night, the night vision of all personnel is of vital importance. It is essential that commanders avail themselves of all possible means to increase the efficiency of their commands at night. This may be attained by:

(1) Selection of personnel for night operational duties on the basis of their night vision ability: assigning men with superior night vision: to vital night duties, those with the poorer to the less important.

(2) Systematic education and training of all personnel in the efficient use of their eyes at night. Good night vision is a matter of indoctrination and training as well as of ability.

(3) Provision of all possible aids to night vision, such as proper red light in lighting devices, night glasses, and the like.

b. The British, the Russians, the U.S. Navy, and the Army Air Forces have all benefited by a program of night vision training similar to that presented in the foregoing paragraph and are continuing strenuous efforts to improve their tests and training methods and aids. It is logical to assume that the Field Artillery will benefit similarly.

c. There has been developed in this study a test which seems the best available at this time for classifying the night vision abilities of personnel in the field; this is the FAS Mass Night Vision Test, described in this report as NVT and specified in detail in Appendix II. Of all known tests, it most closely fulfills these requirements:

(1) It should be simple and within the resources of the average field unit.

(2) The test should be reliable; that is, men should score the same or nearly the same when tested a second or third time.

(3) It should have validity; that is, give results that directly grade and represent a man's ability to see at night under usual field conditions.

(4) It should permit testing of a large number of troops within a short time.

(5) It should be standard or capable of standardization for use throughout the Field Artillery (and other arms).

(6) It should require minimum personnel to supervise, give, and evaluate the tests.

No test which meets these requirements has been available hitherto. The test now optional in Training Circular 44, 1942 is crude and of dubious value.

d. For immediate use by units in the field, the NVT 15 is a design best suited for troops themselves to build. However, since the factors involved in night vision are complex and since field units dislike building items themselves, it would be safer and generally more satisfactory if the Night Vision Tester were built at a central point and distributed. In such a case, the radium-activated or film-strip type NVT is to be preferred.

e. Although the validity coefficients for the best tests developed here are much higher than any previously recorded, the cases are too few for final conclusion. Further validation work should be done along the same or similar lines with a larger experimental group.

f. In the light of the most recent information available, Section IV WD Training Circular No. 44, July 1942 is in considerable part obsolete and should be rescinded or materially rewritten. It should be supplemented by training films, film strips, and suitable charts.

g. A Night Combat Board seems urgently needed to investigate and be responsible for all the problems relating to night combat and to develop the most efficient tactics, techniques, and instruments for night operations for all the arms. It could serve to coordinate and utilize present efforts.

38. <u>RECOMMENDATIONS</u>.--It is recommended that

a. The Field Artillery School Mass Night Vision Tester, Model NVT 15 be approved for immediate use in the field, and that instructions for its construction and use be disseminated to all units.

b. Recommendation (a) above be considered as a necessary, temporary expedient; as soon as possible a standard NVT Model Night Vision Tester be procured and supplied to units through normal channels, preferably of the radium-activated or film-strip type.

c. Unit commanders be directed to test their personnel for the ability to see at night and to utilize the information obtained as a guide for assignments to night duties.

d. A comprehensive program for night vision training of troops be prepared and incorporated in the training programs of replacement training centers and field units. This should include not only preselection of personnel, but also

(1) Orientation, indoctrination, and instruction in proper night vision techniques and aids.

(2) Wide employment of suitable training films, film strips, and charts.

(3) Exercises in recognition of objects at night.

(4) Integration of night vision training with other tactical and technical training conducted at night.

e. Units be furnished with the necessary instructional and training materials to carry out the recommended training program.

f. Night vision research and development be continued elsewhere with adequate staff and facilities to:

(1) Obtain further validation and reliability data on the Field Artillery School Night Vision Tester in its various forms and to study and evaluate other adaptometers or testers developed by the Army Air Forces, U. S. Navy, and others.

(2) Determine means and methods of further improving night vision techniques and aids.

g. There be authorized and formed a Night Combat Board to investigate and have responsibility for all the problems relating to night combat and to coordinate present researches pertaining thereto. This board should have representation from all the arms and services.

Glossary

Brightness	The luminous intensity emitted by a surface in a particular direction per unit area projected in that direction.
Candle	The unit of light intensity. The unit used in the United States is a specified fraction of the average horizontal candlepower of a group of forty-five carbon filament lamps operated at specified voltages (preserved at the National Bureau of Standards).
Candlepower	The light intensity expressed in candles.
Cone Vision	Cone vision is daylight vision. It is so called because of the cone-shaped nerve endings in the retina which are operative at daytime levels of light.
Contrast Sensitivity	The ability to discriminate differences in contrast or relative brightness.
Experimental Group	A group of subjects used for purposes of standardization and comparison of tests.
Dark Adaptation	The process by which the eye becomes adjusted to dim light or night vision; the shift from photopic to scotopic vision. Sometimes used to refer to the state of being dark adapted.
Dark Adapted	The final stage of dark adaptation or the point of maximum sensitivity. The term dark adaptation is sometimes used synonymously.
Foot-Candle	A unit of illumination; the intensity of illumination at a distance of one foot from an international candle. This requires one lumen per square foot and gives a brightness of 1.076 millilamberts.
Foot-Lambert	A unit of brightness equal to the average brightness of any surface emitting or reflecting one lumen per square foot. It is equal to 0.00221 candle per square inch.
Fovea	The visual center of the retina, at which only cones are present and photopic visual acuity is at its best.
Glare Reaction Tester	An instrument used to measure the rate at which dark adaptation occurs.
Innate Aptitude	The aptitude or ability with which a person is born as distinguished from ability which is acquired.

Lambert	A unit of brightness. The emission of one lumen per square centimeter gives a brightness of one lambert; one lumen per square foot is equivalent to one foot-lambert. One lambert equals 929 foot-lamberts or 1,000 millilamberts.
Light Adaptation	The process by which the eye becomes adjusted to bright light or day vision. The shift from scotopic to photopic vision, i.e., the opposite of dark adaptation.
Light Adapted	The final stage of light adaptation. The amount of light entering the eye is gradually reduced, and the eye becomes adjusted to the light present.
Lumen	The unit of light quantity. A uniform point source of one candle emits 12.56 lumens. One lumen of light energy is required to give an illumination of one foot-candle over an area of one square foot.
Mean	The average score of a group. It is obtained by adding the test scores of all persons in the group and dividing the total by the number of persons in the group.
Millilambert	A unit of brightness equal to .929 foot-lambert or 0.00205 candle per square inch.
Ocular	Pertaining to the eye.
Para-foveal	Describing the retinal region lying external to the fovea composed of mixed rods and cones with a preponderance of rods.
Perception	The act of discerning, apprehending, or recognizing.
Photometrics	The science of measuring light intensities.
Photopic Vision	Vision during daytime levels of light.
Retina	The inner coat of the eye containing the photo-sensitive apparatus essential to vision. The rods and cones constitute the outer layer of nerve cells and serve as visual receptors.
Rod Vision	Rod vision is night-time vision. It is so called because of the rod-shaped nerve endings in the retina which are operative at night-time levels of light.
Scotopic Vision	Vision during night-time levels of light.
Snellen Test Chart	A chart used for measurement of visual acuity. It is the standard form eye chart used in all Army eye examinations.

Split-Half (Odd-Even) Reliability	A measure of the reliability of a test obtained by comparing a person's score on the odd items of a test (1, 3, 5, etc.) with his score on the even items of the test (2, 4, 6, etc.). It is used to determine whether a test will rate a person approximately the same upon repeated testing.
Standard Deviation	A statistical measure of variability. It is used to determine and predict the number of people that will obtain certain scores.
Test Character	The object or target used for testing - i.e. Landolt ring, airplane figure, and large T.
Test-Retest Reliability	A measure of the reliability of a test obtained by comparing a person's score on a test with his score obtained on the same test taken again at a later date. It is used in the same way as the split-half reliability.
Trans-Illuminated	A method of lighting in which the light source is placed to the rear of the viewing screen and the light passes through the screen silhouetting the test character placed on the screen.
Visibility	The intensity of a stimulus which evokes visual perception and discrimination.
Visual Acuity	The sharpness or keenness of vision. It is usually measured by means of the Snellen Test Chart - a score of 20/20 being average.
Visual Threshold	The lowest intensity of light at which a subject can make fifty percent correct judgments.

BIBLIOGRAPHY (Incomplete)

A. GENERAL.--

1. American Optical Company. "Dark Adaptation in Relation to Avitaminosis and the Feldman Adaptometer." 1938, (Catalogue).

2. Anon. "Expediting Visual Adaptation to Darkness." Nature (London). May 29, 1943, 151, 617-618.

3. Anon. "Mechanism of Sensitivity Changes of Sense to Darkness." Nature (London). October 24, 1942, 150, 491-492.

4. Brown, Robert H., and Page, Howard E. "Pupil Dilation and Dark Adaptation." J. Exper. Psychology, 1939, 25, 347-360.

5. Cobb, Percy W., and Moss, Frank K. Extract from "The Four Variables of the Visual Threshold." Journal of the Franklin Institute, January-June 1928, 205.

6. Conner, J. Preston, and Genoung, Robert E. "An Experimental Determination of the Visual Thresholds at Low Values of Illumination." Extract from Journal of the Optical Society of America.

7. Craik, K. J. W., and Vernon, M. D. "Perception During Dark Adaptation." From the Cambridge Psychological Laboratory, 1942, 32, 206-230.

8. Craik, K. J. W., and Vernon, M. D. "The Nature of Dark Adaptation." Brit. J. Psychol., 1941, 32, 62-81. Excerpt from "Bulletin of War Medicine," May 1942, 2.

9. Detweiler, S. R. "Summary of Comparative Anatomical Studies of the Eye with Especial Reference to the Photoreceptors." College of Physicians and Surgeons, Columbia University, New York, November 20, 1939.

10. Edridge and Green. "The Solution of the Problem of Vision." Excerpt from Chemistry & Industry, January 1939, 58.

11. Edridge and Green. "Vision and Colour-Vision." Journal of the Society of Chemical Industry, 59.

12. Feldman, J. B. "Dark Adaptation--Its Place in Accident Prevention." Industrial Medicine, March 1940.

13. Feldman, J. B. "Light Threshold--Its Clinical Evaluation (Dark Adaptation)." Arch. Ophth., September 1941, 26, 466-471.

14. Hartline and McDonald. "Frequency of Seeing at Low Illuminations." Report No. 110, January 1943, NRC, Division of Medical Science, Committee of Aviation Medicine.

15. Harvey, Roger A. "A Rapid Dark Adaptation Test." Radiology, March 1942, 38, 353-354.

16. Hecht, S. "Photochemistry of Visual Purple." Extracted from the Journal of General Physiology, 19.

17. Hecht, S. "Rods, Cones and the Chemical Basis of Vision." Physiol. Review, 1937, 17, 239.

18. Holmes, William John. "Night Vision." Ophthalmologic Reviews, Archives of Ophthalmology, August 1943, 30.

19. Luckiesh, Matthew, and Moss, Frank K. "The Measurement of Visibility." Journal of the Aeronautical Sciences, January 1942, 9.

20. Luckiesh, Matthew, and Moss, Frank K. "The Ability to See Low Contrasts at Night." Journal of Aeronautical Sciences, May 1942, 9.

21. Luckiesh, Matthew, and Moss, Frank K. "The Luckiesh-Moss Test Chart Illuminator." American Journal of Ophthalmology, September 1941, 24.

22. Luckiesh, Matthew, and Moss, Frank K. "A Summary of Researches in Seeing at Low-Brightness Levels." Illuminating Engineering, April 1943, 38.

23. Lythgoe, R. J. with assistance by Dorothy E. Corkill and with a section by E. S. Pearson. "The Measurement of Visual Acuity." Extracted from Medical Research Council Reports of Great Britain, 168-174.

24. McCartney, Lt. Comdr. James L. "Tropical Neuropsychiatry." War Medicine, April 1943, 3.

25. Osterberg, G. "Topography of the Layer of Rods and Cones in the Human Retina."

26. Porter, L. C. "Blackout Lighting."

27. Riddal, W. J. B. "Two Clinical Tests for Night Blindness." Tr. Ophth. Soc. U. Kingdom, 1940, 60, 181.

28. Robertson-Hope, W. J. "Night Vision and Night Blindness." New Zealand Medical Journal, August 1942, 159-166.

29. Strongin, E. J., and Bull and Korclain. "Visual Efficiency During Emotional Hates." J. Psych., July 1941, 12, 3-6.

30. Taylor, A. H. "Brightness and Brightness Meters." Illuminating Engineering, January 1942, 37.

31. Troland, L. T. "The Present Status of Visual Science." NRC, December 1942, 62, 68, 80, 83, 97.

32. Wald, George, and Clark, Anna-Betty. "Visual Adaptation and Chemistry of the Rods." Extract from Journal of General Physiology, September 1937, 21.

33. Wittkower, E., Roger, T. F., Scott, G. I., and Semenoff, B. "Night Blindness. A Psycho-physiological Study." Brit. Med. J., October 25, 1941, 2, 571-5; November 1, 1941, 2, 607.

34. Wosika, Paul H. "Night Blindness of War." War Medicine, September 1943, 4.

B. RESTRICTED AND CONFIDENTIAL.—

35. U. S. Army, Army Air Forces. "Visual Fields in the Dark Adapted State." SAM 35-1, December 7, 1942.

36. U. S. Army, Army Air Forces. "A Small Light Threshold Meter." SAM 69-3, September 13, 1943.

37. U. S. Army, Army Air Forces. "Sulpha Drugs and Dark Adaptation." SAM 91-1, November 1, 1942.

38. U. S. Army, Army Air Forces. "Pupillary Size in Relation to Dark Adaptation." Report No. 1, Project No. 16, April 21, 1942.

39. U. S. Army, Army Air Forces. "The Comparison of the Hecht Adaptometer and the Miles Illuminous Disc Adaptometer." Report No. 2, Project No. 17, March 31, 1942.

40. U. S. Army, Army Air Forces, School of Aviation Medicine, Randolph Field, Texas. "A Small Light Threshold Meter." Report No. 1, Project No. 69, July 22, 1942.

41. U. S. Army, Army Air Forces, School of Aviation Medicine, Randolph Field, Texas. "A Small Light Threshold Meter." Report No. 2, Project No. 69, January 23, 1943.

42. U. S. Army, Army Air Forces, School of Aviation Medicine, Randolph Field, Texas. "A Model Photoelectric Machine Gun and Target Range for Indoctrination in Night Gunnery under Conditions of Extreme Darkness." Report No. 1, Project No. 81.

43. U. S. Army, Army Air Forces, Matériel Division. "Aspects of Night Visual Efficiency." Report No. 1, Project No. 106, May 1, 1943.

44. U. S. Army, Army Air Forces, Matériel Division. "Night Vision Tester." Report on results of conference on design of Night Vision Testers under construction by Eastman Kodak Company for AAF use. ENG-M-49-695-12A.

45. U. S. Army, Army Air Forces, Materiel Division. "Test for Demonstration of the Effects of Anoxia on Vision." ENG-M-49-695-12H, January 12, 1943.

46. U. S. Army, Army Air Forces, Matériel Division. "Night Gunsights." ENG-M-49-695-12J, January 25, 1943.

47. U. S. Army, Army Air Forces, Matériel Division. "Form Discrimination at Low Illuminations." ENG-M-49-695-12K, February 5, 1943.

48. U. S. Army, Army Air Forces, Matériel Division. "Dark Adaptation in Army Air Corps Pilots." Exp-M-54-653-30.

49. U. S. Army, Army Air Forces, Matériel Division. "Dark Adaptation in Army Air Corps Pilots." Exp-M-54-653-51.

50. U. S. Army, Army Air Forces, Matériel Division. "Effect of Altitude on Dark Adaptation." Exp-M-54-653-63.

51. U. S. Army, Army Air Forces, Matériel Division. "Dark Adaptation Apparatus (Rotating Hexagon)." Exp-M-54-653-69A, November 20, 1941.

52. U. S. Army, Army Air Forces, Matériel Division. "Dark Adaptometer." Exp-M-54-653-69B.

53. U. S. Army, Army Air Forces, Matériel Division. "Dark Adaptometer." Exp-M-54-653-69C.

54. U. S. Army, Army Air Forces, Matériel Division. "Night Vision Tester." Report on trip to Philadelphia and New York in regard to development of instrument to test night vision. Exp-M-54-653-69D.

55. U. S. Army, Army Air Forces, Matériel Division. "Dark Adaptation." Exp-M-54-653-89.

56. U. S. Army, Army Air Forces, Matériel Division. "Night Vision." Report on trip by Dr. E. A. Pinson to initiate studies on night vision at School of Aviation Medicine, Randolph Field, Texas. Exp-M-54-653-89A.

57. U. S. Army, Army Air Forces, Matériel Division, School of Aviation Medicine, Randolph Field, Texas. "Comparison of the Hecht Adaptometer and the Miles Illuminous Disc Adaptometer." Tables 1-4B, Photos.

58. U. S. Army, Army Air Forces, Navy Testing Unit. Laredo Army Air Field, Laredo, Texas. "Night Vision Testing Data."

59. U. S. Army, Armored Force Medical Research Laboratory, Fort Knox, Kentucky. "Personnel Classification and Selection Test for Night Vision." December 3, 1943.

60. U. S. Army, Field Artillery School, Fort Sill, Oklahoma. "Night Observation--Training in Proper Use of the Eyes." August 1942.

61. U. S. Army, General Staff, G-2 Section. "Night Vision of AA Personnel (Great Britain)." 1942.

62. U. S. Army, General Staff, G-2 Section. "Night Binoculars (Great Britain)."

63. U. S. Army, General Staff, G-2 Section. "Night Flash Ranging." Report No. 60859, September 24, 1943.

64. U. S. Army, General Staff, G-2 Section. "Tactical Employment of Field Artillery Observation Battalions--Night Vision." Report No. 46663, February 19, 1942.

65. U. S. Army, General Staff, G-2 Section. "Tactical Employment of Field Artillery Observation Battalions--Night Vision." Report No. 54605, March 6, 1943.

66. U. S. Navy, Medical Research Institute, National Naval Medical Center, Bethesda, Maryland. "Determination of Effect on Dark Adaptation of Varying Intensities of Illumination in Ready Rooms." Report No. 1, Project X-162, June 2, 1943.

67. U. S. Navy, Medical Research Institute, National Naval Medical Center, Bethesda, Maryland. "Determination of Effect on Dark Adaptation of Varying Intensities of Illumination in Ready Rooms—Newly Discovered Fluctuations of Periodic Nature Occurring in Dark Adaptation Thresholds." Report No. 2, Project No. X-162, September 24, 1943.

68. U. S. Navy, Medical Research Laboratory, Submarines, Atlantic Fleet. "Handbook on Night Lookout Training." May 1, 1943.

69. U. S. Navy, Medical Research Laboratory, U. S. Submarine Base, New London, Conn. "Field Tests of the Radium Plaque Adaptometer." November 26, 1943.

70. U. S. Navy, Research Division, Bureau of Medicine and Surgery, Washington, D. C. "The Measurement of Thresholds of Perception and Discrimination." April 1943.

71. U. S. Navy, Bureau of Naval Personnel, Training Division, Standards and Curriculum Section. "Curriculum of our Lookout Training." March 1943.

72. U. S. Navy, Liljencrants, Commander Eric, (MC), USN; Swanson, Commander Clifford A., (MC), USN; and Carson, Lieut. Commander Leon D., (MC), USN. "Use of the Eyes at Night." U. S. Naval Institute Proceedings, June 1942.

APPENDIX I

NIGHT OBSERVATION

Training in Proper Use of the Eyes

(This is a reproduction for interim use pending completion of a newer report which will contain results of tests and studies currently in progress as well as the latest tests and information pertaining to this important subject.--S-2 Section, Field Artillery School.)

1. INTRODUCTION.--

a. Vision at night is of the utmost importance in war. The danger of enemy surprise is greatest during darkness or semi-darkness. It is then that the enemy can carry out all kinds of movements and actions with much greater safety and deception than in daytime. To be able to see or discern even part of these movements is unquestionably of value. The enemy relies on darkness in place of the usual cover or concealment and much of his activity will be visible to the night observer. Hence, it is evident that every effort should be taken to improve the night vision of combat and observation personnel.

b. Fortunately, there are measures that can be taken in training our soldiers and officers on how best to use the eyes at night. These measures are based not only on past Army experience and information, but also on recent discoveries of the British Antiaircraft and Coast Defense Services and of our own Navy and National Research Council. The stakes are too high to ignore this opportunity for improving night vision.

2. THE EYE AND VISION.--

a. The eye is an extraordinarily complex instrument; vision is even more complex. The structure of the eye is such that people really have "day eyes" and "night eyes," which are distinctly different, which must be used differently, and which see differently. The following fact gives some idea of the great variations between day and night vision. After exposure to a bright light for a few minutes, the sensitivity of the eyes must increase a million times or more for use in darkness. This necessary increase in sensitivity takes a half hour or more to achieve.

b. Light waves are similar to radio or electrical waves. Visible light is a small fraction of the electromagnetic spectrum, and white or daylight is a composite of the various colors of the visible spectrum, or rainbow, each color being of a slightly different wavelength. Hence, intensity (or quantity) and frequency (or quality) are the two factors determining brightness and color. The eye may be compared to a camera combined with a radio receiver. It is so constructed that light entering the pupil is converged on the retina by a lens; the retina is a tissue screen on the back of the inside of the eye. Here the light is converted to minute electrical currents and carried to the brain via the optic nerve, giving rise to the sensation of sight.

c. A cell layer made up of two types of cell structures enables the retina to work in darkness as well as in light. These two types of cells are known as cones and rods. (See figure 1.) The rods and cones, so named because of their shapes, are really nerve endings. Broadly speaking, cone vision is day vision (or day eyes) and rod vision is night vision (night eyes). The cones distinguish colors and can function in dim light down to the level of bright moonlight. This level

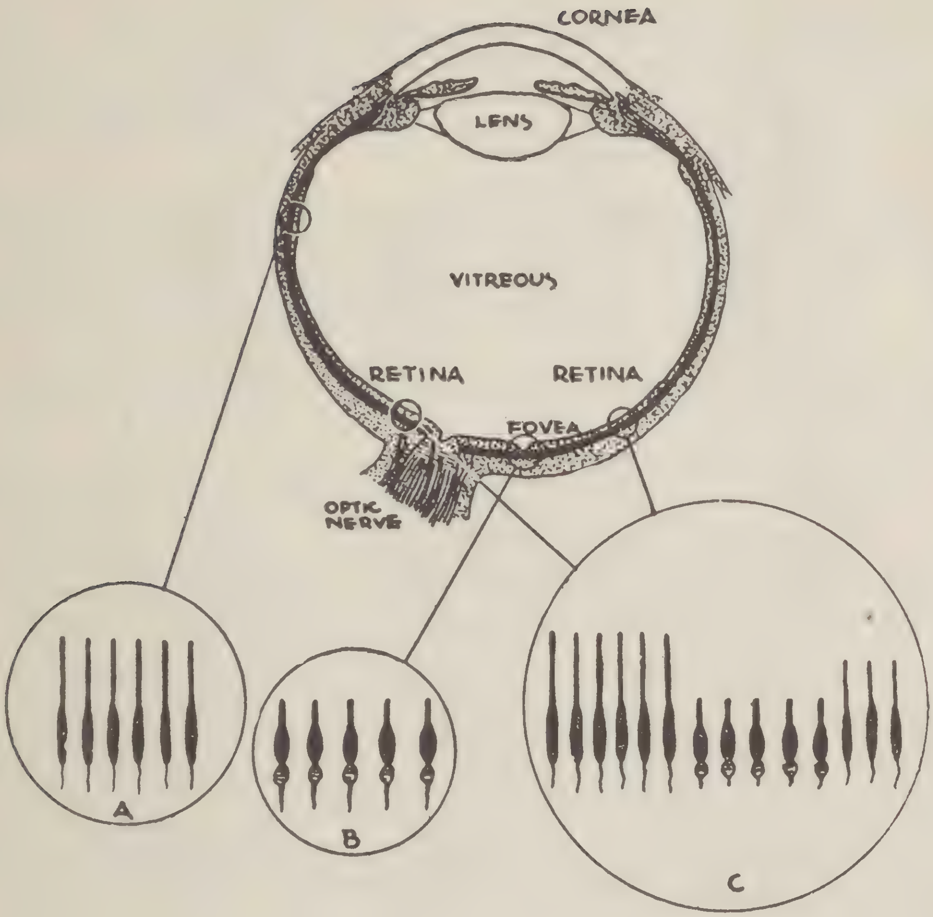


FIG. 1

Cross section of the eye with magnified highly schematic diagrams to show (A) peripheral portion of the retina where only rods are present, (B) fovea centralis at which only cones are present, and (C) parafoveal areas near the fovea at which rods and cones are about equally represented. Actually the microscopic structure of the retina is vastly more complicated than illustrated here. (Reproduced from U. S. Naval Institute Proceedings, June, 1942).

(1/1000 foot-candle*) is their limit of sensitivity, and below it color recognition is not possible. The rods, however, function not only in bright light but are also extremely sensitive to very weak light. However, rod vision cannot distinguish colors.

d. The rods and cones are not distributed evenly over the retina. Both are present over most of it, but at the edges of the retina there are only rods. This distribution of rods enables one to see out of the "corner of the eye" and to perceive objects in motion. As the center of the retina is approached, cones appear; they become more and more numerous until at the visual center, or fovea, of the retina, there are only cones and no rods. Hence, in day vision the most sensitive portion of the retina is the fovea, which for night vision is practically useless. Therefore, to see best at night, one must look out of the "corner of the eye" where the rods are present in profusion.

e. Besides the differences in sensitivity of the cones and the rods, the pupil is also an important factor. During the day, the diameter of the pupil is from 0.1 to 0.2 inch, thus restricting the amount of light entering the eye. At night, the eye must gather all the light possible, and the pupil may dilate until its diameter is from 0.25 to 0.3 inch. The maximum possible increase in the area of the pupillary opening is over 30 times. This increase in the size of the pupil has an important bearing on efficiency in using optical instruments at night and will be referred to again.

f. We all know that when we go from bright daylight or a brightly illuminated room into darkness, such as into a motion picture theater, we are blind for quite a while. Our vision gradually improves, however; and in 20 minutes to a half hour, we are able to see things at first invisible. This phenomenon is due to chemical changes within the rods and cones. These changes cause changes in sensitivity to light as well as changes in the size of the opening of the pupil.

g. When we go from dimly lighted places into brightly lighted ones, we are dazzled for a short while, but the eyes quickly become adapted to the bright light. This process is so rapid that it is completed in one to two minutes. It is evident that the eyes become light adapted far faster than they become dark adapted. Hence, a brief exposure to bright light will cancel the effects of a half hour spent in becoming dark adapted. However, the rods are relatively insensitive to red light and cannot adapt to intensities below those recognizable by the cones. Since red light does not interfere with dark adaptation, it is of great importance in night lighting.

h. Normal people vary in the power of dark adaptation. The proper use of the eyes, however, may give better night vision than improper use of eyes with superior powers of adaptation. Training and practice can greatly improve night vision.

3. PROCEDURES TO IMPROVE NIGHT VISION.--

a. There are several measures that should be taken to improve the night vision of Army personnel. They are

(1) Selection of personnel.

(2) Training in establishment of dark adaptation.

(3) Training in preserving and maintaining dark adaptation.

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*One foot-candle is the intensity of illumination given by a standard candle at a distance of one foot.

(4) Instructions in the techniques of observing, including studies of silhouettes.

(5) Use of night optical instruments.

The above measures should be reduced to a standard operating procedure, and constant training and strict adherence to them should be insisted upon at all times.

b. Because all combat personnel will have to move about and take posts in complete darkness, the value of selection is somewhat limited. However, personnel manning observation posts and using night and survey instruments should have normal or better visual and auditory acuity. No man whose visual acuity is less than 20/20 in each eye should be selected. Also the telescopic and stereoscopic performance of each soldier should be tested. If otherwise qualified, those men with the highest dark-adaptation ability should be chosen. The tests should be simple and not require special apparatus. In general, the standards established by the Air Corps Medical Service, insofar as they apply to vision, hearing, and emotional stability, are an excellent guide in selecting observation personnel.

c. Not only should these special personnel have keen sight and hearing and be emotionally stable, but they should possess excellent stamina and be considerably above average in mental ability. They should be well trained as soldiers and thoroughly grounded in scouting and patrolling. They should be able to express themselves well and make reports without exaggeration.

d. Before going on night duty or any duty which requires observation in darkness, a soldier should be adequately prepared for dark adaptation. The simplest and best way to achieve dark adaptation is, of course, to remain in complete darkness for at least one half hour before going on duty, taking care to avoid any exposure to light in the interval between achieving dark adaptation and commencing observation in the dark. Even a momentary flash of light will undo most of the dark adaptation. The time needed for dark adaptation can be lessened if the soldier has been on duty in a very dimly lit room for some time and not exposed to flashes of bright light.

e. If it is absolutely necessary for the night-adapted observer to have illumination for any reason, he should be fitted with special dark-adaptation goggles of the Navy type, which permit transmission of sufficient red light to give cone vision but do not interfere with the dark adaptation. Not any red goggles will do. Not only must light not leak through the frames, but the lenses must be designed to admit light in a precisely specified wave band only (wavelengths beyond 600 millimicrons). He should wear these goggles for an hour before going on duty.

f. Since the dark adaptation of one eye is independent of the dark adaptation of the other, when exposure to light is absolutely necessary, one eye can be thoroughly covered with a patch to maintain its dark adaptation while the other is used. However, this expedient will result in impairment of depth perception and in considerable restriction of the total field of vision until the exposed eye has had time to become adapted again. The method is fairly satisfactory for use in observing distances beyond 500 feet.

g. If the observer is exposed to gunfire, searchlights, and the like, try to have him screened from these as much as possible; in any event, train him to avoid looking at light flashes and to close one or both eyes when flashes occur.

h. It is frequently impossible not to use some light for reading instruments and the like. The illumination should be of minimum intensity and used for as brief a period as possible. Staring at an instrument should be avoided. Lights for this purpose should be red of the proper wave band. Lenses of flashlights and other lights to be used should be of the same red, and instruments at present equipped with devices for night light employing white light should be converted.

4. TECHNIQUES OF OBSERVING AT NIGHT.--

a. The normal daytime center of vision is blind at night. Hence, in darkness, the observer should be trained to look out of the corner of his eye since the sensitive rods are most profuse in this part of the retina. This takes conscientious practice. The best angle is about 10° to the side or above or below the axis of the eye in normal daytime vision. (See figure 2).

b. The observer should also learn to move his eyes frequently and not to stare when in dim light. This action is called scanning. The eyes actually see little or nothing while in motion but are most sensitive after having moved. They should move in short jumps systematically from left to right and right to left in searching the terrain and sky line and, of course, should be on the lookout for objects which can be seen from the corner of the eye.

c. Since night vision is colorless vision, it depends on contrast. Objects are seen in contrast to the background and show up only if they are lighter or darker than the contrasted background. Hence, anything that reduces contrast will seriously impair night vision. Goggles, instrument lenses, and such must be kept scrupulously clean. Reflection or glare also reduces contrast and makes night vision difficult or impossible.

d. In all probability, objects will be recognized by their silhouettes, and study of silhouettes of all types, from all angles, and at varying distances should be assiduously pursued.

e. Since the most primitive response of the retina is motion, most objects will be picked up by their motion. However, fast moving objects at night are less detectable than slow moving. Also, small objects cannot be seen at night, and large objects with projections, such as trees, may appear considerably smaller because the twigs, branches, and other details cannot be seen at all. Observers should be trained to notice the difference in appearance, by day and by night, of various objects.

5. NIGHT OPTICAL INSTRUMENTS.--

a. Proper night-observing instruments can materially improve night vision. Most, if not all, fire-control instruments are not suited to night observation. A suitable night optical instrument includes an exit pupil of 0.3 inch and an objective lens of adequate size and has a wide field of vision. High magnification is unnecessary and generally impractical.

b. In a good night instrument there is a distinct gain in visibility because of magnification, which is often more than sufficient to offset the inevitable loss of light in the optical system. Because of physiological or psychological factors, a small, very dimly illuminated object appears brighter, and more details may be discerned when there is magnification, even though there is no actual change in brightness. Using a good night instrument, an observer will be able to see objects otherwise not visible.

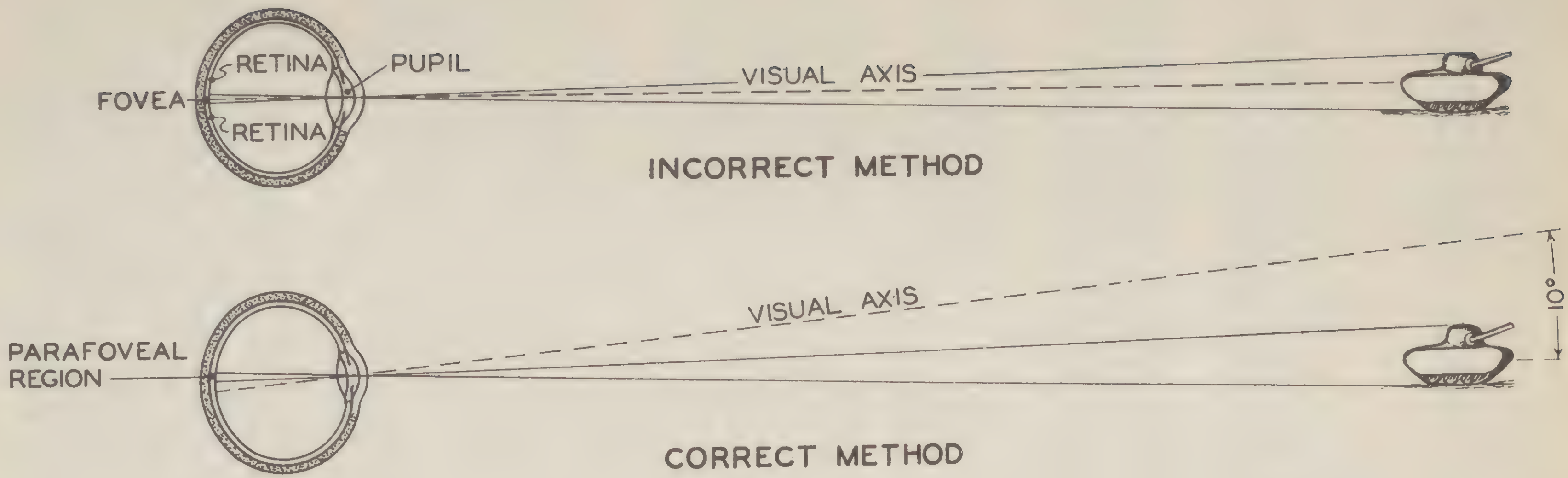


FIG. 2

Illustration of how to use the corners of the eyes at night. Night targets are best seen by looking about 10 degrees left or right, or 10 degrees above or below.

c. In using a night instrument, the eye should be protected from all stray light in order that the pupil may dilate as much as possible and dark adaptation not be reduced. If a monocular instrument is used, the eye not in use should be covered. Instruments should be so mounted that they are absolutely steady; even the slightest movement or wavering will seriously affect observation or make it useless.

6. OTHER FACTORS IN NIGHT VISION.--

a. Distraction, fatigue, discomfort, and so on will impair night vision. Unnecessary movement, talking, nearby dash lights have adverse effects. Fatigue and discomfort caused by clothing, coldness, or wetness play a large part in night observation.

b. Much has been said and written about increasing the sensitivity of the eyes by eating vitamins A and C. While people suffering from a serious shortage of these vitamins and having dark vision one hundred times less than normal are helped by eating these vitamins, no superabundance of them will raise night vision above normal. As a rule the average soldier is so well fed that this is no factor.

c. In observation at high altitudes, such as in a plane or in high mountains, night vision is one of the first faculties adversely affected, and oxygen should be used at altitudes above six or eight thousand feet. The use of oxygen at night should begin at much lower altitudes than in daytime.

d. Excessive smoking and the use of alcohol will reduce visual efficiency under certain conditions. Certain drugs will temporarily decrease fatigue and aid alertness. The most familiar of these is caffeine, which is found in coffee. A drug which acts similarly to caffeine and which seems to have certain advantages over it is benzedrine. However, since there are such great individual variations, no set rules governing the use of these drugs can be given. The advice of medical officers should be obtained, but the vast majority of drugs are likely to do more harm than good when used in an effort to aid night vision.

e. Race may be an important factor in night vision: there is a theory that Negroes have superior ability to see at night. However, the only confirmation of this theory that the writer has been able to find is a report of a more or less haphazard experiment at Fort Bragg. The experiment was conducted in a field on a dark night. A stick with squares of white cardboard at each end was held up one hundred feet away from the subjects, seven white and eight Negro soldiers. They were asked whether or not the stick was vertical or horizontal. Every Negro was able to determine the position of the stick, but most of the white soldiers had to get within fifty feet to be able to identify its position. Much more proof than this is necessary to substantiate this theory.

f. The skies and the atmosphere, of course, are controlling factors in night vision as they are in daytime vision. No matter how dark a night may seem, there is no really complete absence of light. A certain amount of starlight, moonlight, sunlight, and light from distant terrestrial objects reaches the night observer. Clouds, dust, smoke, fog, mist, rain, and ice crystals are among the more obvious items affecting light conditions. (There are certain other less obvious effects caused by phenomena of refraction, reflection, diffraction, polarization, etc.) Even with apparently clear weather conditions, there will be marked differences in night vision at different times and places because of veiling, absorption, and other effects of varying amounts of dust, mist, and the like in the atmosphere.

7. RECOMMENDATIONS.--

a. That a standard operating procedure be established in all observation and combat organizations for the improvement and maintenance of the night vision of the personnel. As an amplification of the measures mentioned in Section 3 of this report, the following is a suggested procedure:

(1) Careful selection of personnel.

(a) Individuals basically good soldiers.

(b) Fully trained in scouting and patrolling.

(c) Physically and emotionally sound; high mental ability.

(d) Customary eyesight tests augmented by special tests to determine degree of dark adaptability.

(2) Instruction in methods of dark adaptation.

(a) Proper waiting period in darkness before duty period.

(b) Use of dark-adaptation goggles.

(c) Special expedients.

(3) Maintenance of dark adaptation.

(a) Blindfold drill in usual duties until completely adept at getting about and handling instruments in darkness.

(b) When lighting is imperative, only the proper red lights employed with minimum intensity.

(c) Observers screened from lights, such as flashes, gun flashes, headlights, and flashlights, and trained to avoid looking at them by quickly closing one or both eyes.

(4) Training in technique.

(a) Looking out of corner of eye.

(b) Scanning.

(c) Contrast.

(d) Difference of objects by day and by night.

(e) Recognition of silhouettes.

(f) Auxiliary use of sense of hearing.

(5) Night optical instruments (properly designed, mounted, and illuminated) supplied and utilized.

(6) General.

(a) Scrupulous cleanliness of equipment such as goggles, lenses, and windshields.

(b) Frequent periodic relief of observers; maximum observation period of one-half hour under favorable circumstances.

(c) Avoidance of undue fatigue and discomfort.

(d) Unwell observers relieved of night observation duties.

(e) Frequent periodic re-examination of personnel.

(f) Constant training in adherence to principles and procedure.

b. That studies be made to ascertain whether or not any race has superior night vision.

c. That our present optical fire-control instruments be altered or changed to attain maximum night efficiency.

REFERENCES

1. Anon. "Vision." Encyclopedia Britannica.

2. Anon. "How to Use Your Eyes at Night." Infantry Journal, August 1942. (From Science Service, based on material furnished by the National Research Council.)

3. Anon. "Cat-eyes." Time, June 30, 1941.

4. Feldman, J. B. "Light Threshold: Its Clinical Evaluation." Archives of Ophthalmology, September 1941.

5. Gardner, I. C. "Elementary Optics and Applications to Fire-Control Instruments." Government Printing Office, 2d Edition, 1924.

6. Humphreys, W. J. "Physics of the Air." 1940.

7. Liljencrantz, Commander Eric; Swanson, Commander Clifford A.; and Carson, Lieut. Commander Leon D. "Use of the Eyes at Night." U. S. Naval Institute Proceedings, June 1942.

8. Medical Field Service School, Carlisle Barracks. "Aviation Medicine."

9. U. S. Army, General Staff, G-2. "Night Vision of Anti-Aircraft Personnel. (Great Britain)."

10. U. S. Army, General Staff, G-2. "Night Binoculars. (Great Britain)."

11. War Department. FM 30-10,"Military Intelligence, Observation."

12. War Department. Training Circular No. 44, July 1942.

13. War Department. Military Intelligence Service. "How to Use Your Eyes at Night." Intelligence Bulletin, February 1943, 1.

14. Wittkower, E., Rodger, T. F., Scott, G. I., and Semonoff, B. "Night Blindness: A Psycho-physiological Study." British Medical Journal, October 25 and November 1, 1941.

APPENDIX II

SPECIFICATIONS FOR FIELD ARTILLERY SCHOOL NIGHT VISION TESTER, MODEL NVT, FOR MASS TESTING

Part I

The NVT is a mass night vision tester which can be built with the tools and resources available to the average Field Artillery battalion. It consists of a viewing chamber with a rotating head, six individual indicators, a BD-71 switchboard for recording scores, sufficient W-110 or W-130 telephone wire for proper connections, and two EE-8 field telephones for intercommunication.

1. VIEWER (Dwg. NVT - 201).--

a. The viewer is designed to produce an even distribution of light on the viewing screen within the limits of the light source employed and the size of the hole through which the light is projected. It is important that the interior dimensions of the viewer be maintained. The outside dimensions may vary slightly according to the thickness of the material used.

b. The construction of the joints and corners of the viewer shown in Dwg. NVT - 201 insures light-tight corners. If facilities are not available for insetting sides and back as shown in the figure, another method of construction may be employed, provided measures are taken to make the box light-tight. Joints and corners may be taped on the inside or outside, or both. A satisfactory viewer has been constructed of wallboard nailed to a wooden frame. The corners and joints were sealed with heavy gummed-paper tape. The top of the viewer should be removable, but light-tight.

c. The inside of the viewer should be painted with a flat white paint. The white paint used for painting white recognition stars on vehicles is suitable. The outside of the box should be painted a flat black, olive drab, or other dull dark color which will keep the surface from reflecting the light.

d. The front of the viewer should be covered with standard white tracing cloth. This has been found to be the best material for the purpose, as it gives an even distribution of light over the entire screen.

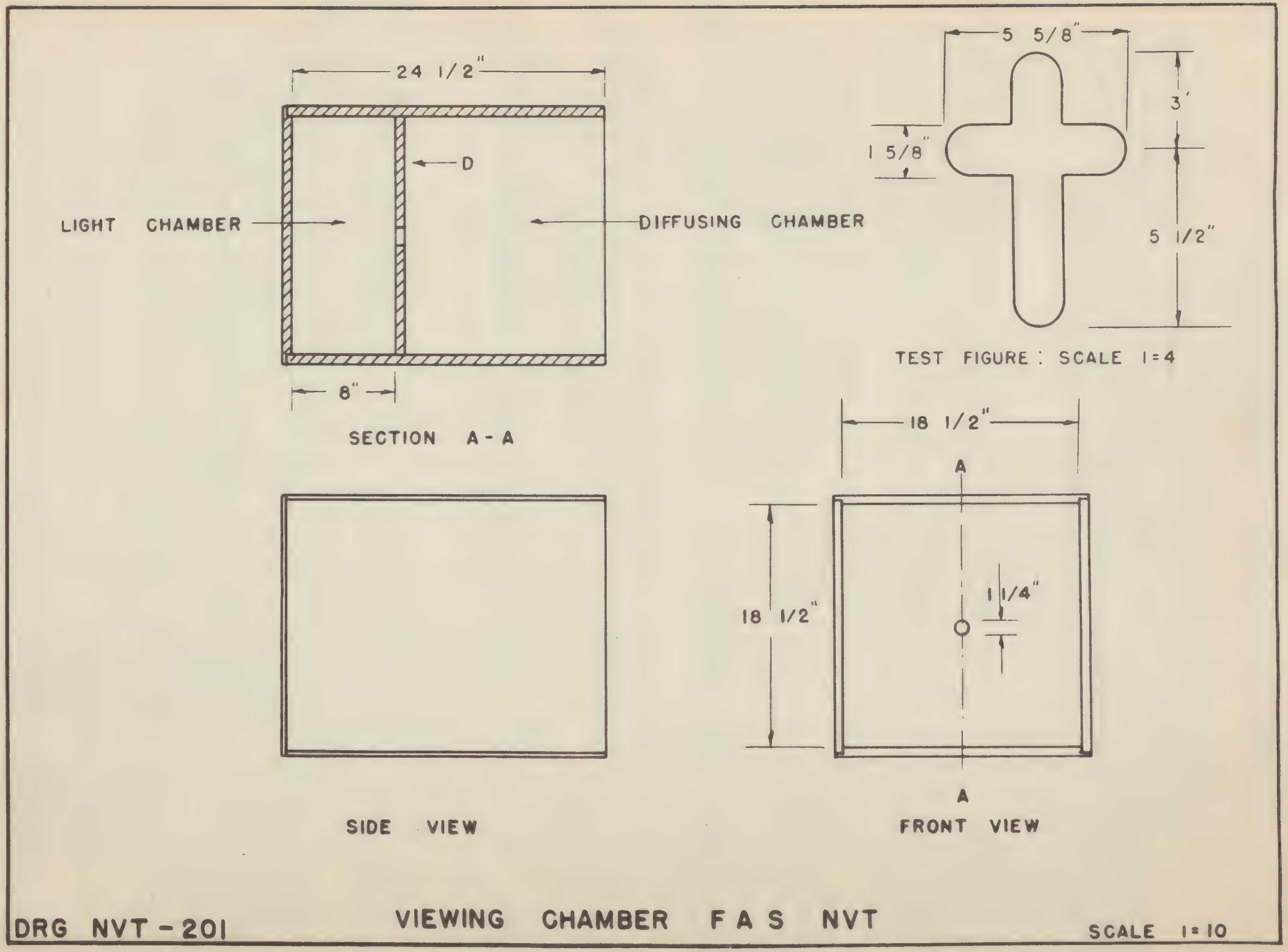
2. LIGHT SOURCE.--

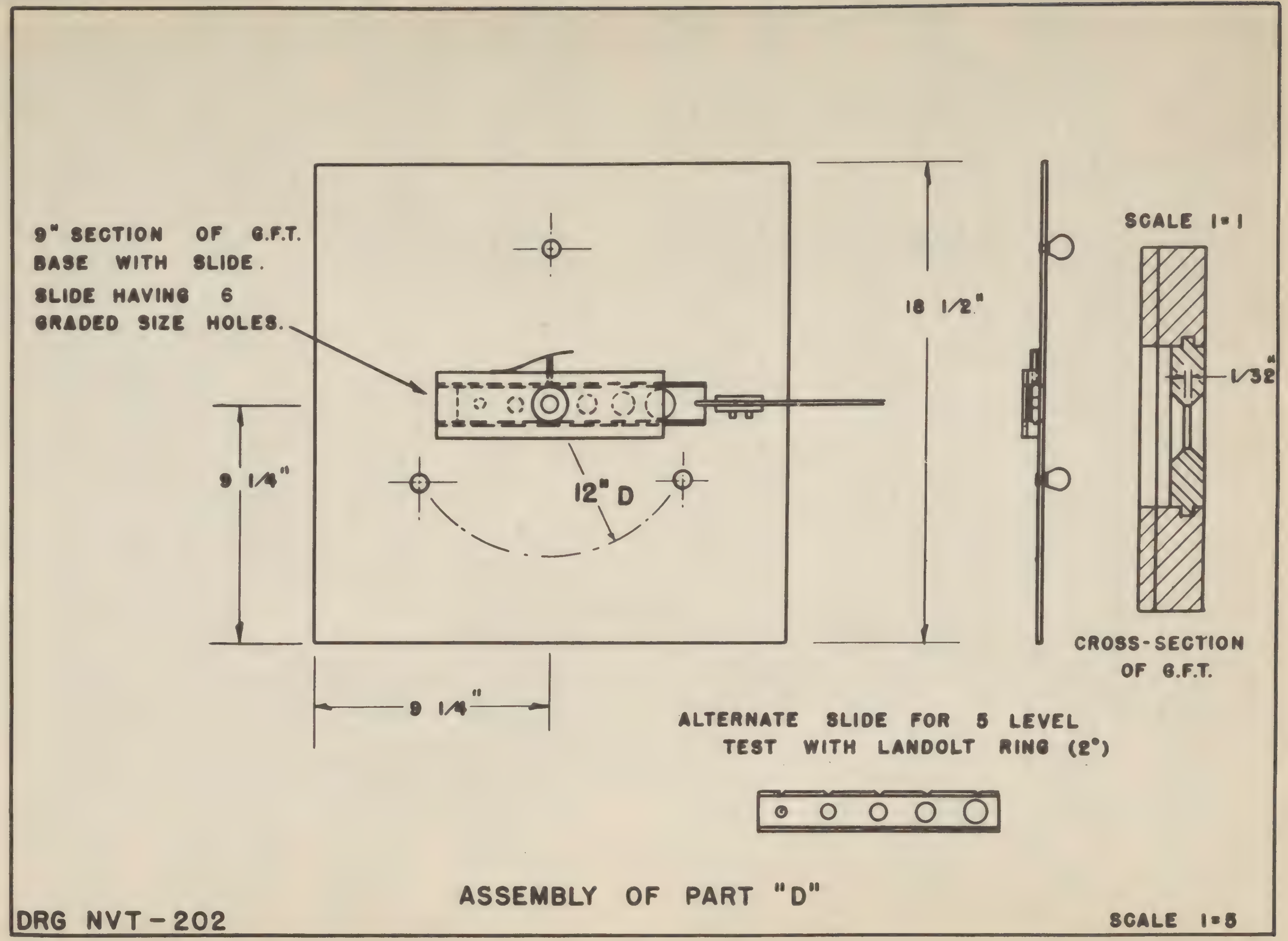
a. The light for the viewer comes from three 3-candlepower, 6-8 volt lamp bulbs (Mazda 63) of the type used in the taillights of many vehicles.

b. These bulbs are wired in parallel and burned at a constant voltage of 3.5 volts by means of a 6-volt storage battery and a low-voltage circuit tester. To maintain this voltage, the bulbs are placed in series with the resistance unit of the low-voltage circuit tester, and the rheostat is regulated until proper voltage is impressed on the lines. Voltmeter leads of the low-voltage circuit tester must be placed across the line. (Exhibit D shows viewer with rotating head, low-voltage circuit tester, and 6-volt storage battery.) It is important that the battery be kept highly charged and that the voltage be maintained at a constant level of 3.5 volts during testing.

3. LIGHT INTENSITIES.--

a. The various light intensities are obtained by means of a slide or circular disc in which holes of graded size have been drilled in such a way that


24 1/2"
LIGHT CHAMBER
D
DIFFUSING CHAMBER
8"
SECTION A - A
5 5/8"
3'
1 5/8"
5 1/2"
TEST FIGURE : SCALE 1=4
18 1/2"
A
18 1/2"
1 1/4"
A
SIDE VIEW
FRONT VIEW
DRG NVT - 201
VIEWING CHAMBER F A S NVT
SCALE 1=10



ASSEMBLY OF PART "D"

the holes can be uncovered separately.

b. A nine-inch section of an old Graphical Firing Table is excellent for this purpose, as its construction makes it light-tight. If a GFT section is used, it is fastened to the front of the partition with the face of the rule against the partition. (See Dwg. NVT - 202.) Thus attached, the slide will rub slightly against the partition, making the surface light-tight.

c. To facilitate proper aligning of the holes in the slide, a notch is cut in the tongued edge of the slide directly above the center of each hole. A plunger to indicate the stages of light intensity can be made from a short piece of nail with a rounded end. Slight pressure may be applied to the plunger by means of a leaf spring made from the blade of an old hack saw.

d. The diameters of the holes for the six stages of light intensity are 9/32", 7/32", 5/32", 1/8", 3/32", and 1/16". If these holes are drilled in any material thicker than 1/32" (such as the slide of a Graphical Firing Table), the holes must be countersunk until the lip is no wider than 1/32". If the GFT slide is used, countersinking from both sides is preferable.

e. The diameters of the holes for the alternate five-level test with the 2° Landolt Ring are 3/8", 1/4", 5/32", 1/8", and 1/16".

f. A circular piece of metal may be used in place of the Graphical Firing Table, although it is difficult to drill true holes in thin metal. This metal disc can be rotated by means of a shaft of welding rod run through the back of the viewer. This type of construction was used in the QM packing-box model (See Exhibit E) with satisfactory results. It is difficult, however, to keep the disc flat against the face of the partition so that light will not leak around the edges.

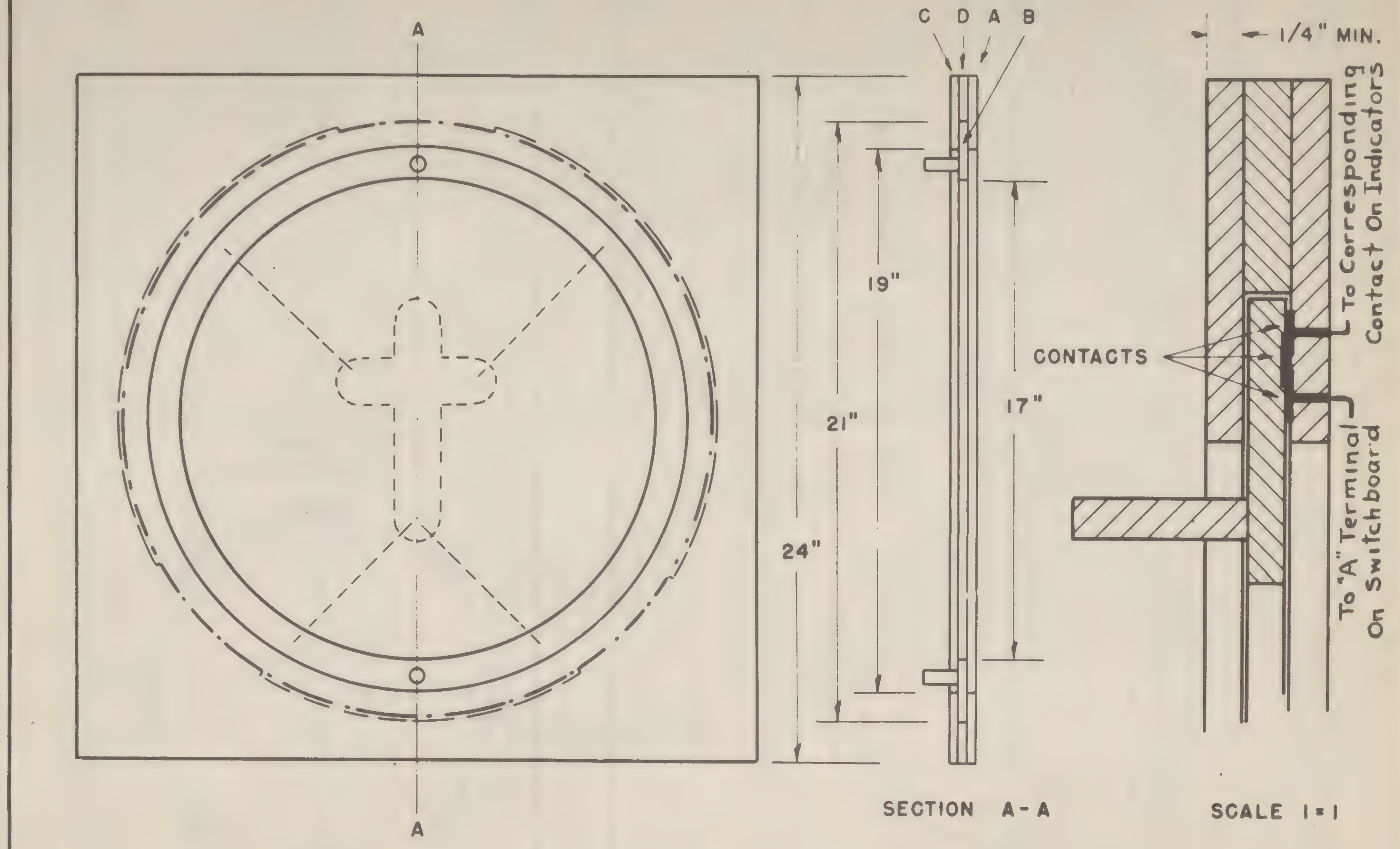
4. ROTATING HEAD. (Dwg. NVT - 203 and NVT - 204).--

a. The rotating head can be made either electrical or nonelectrical. Although the electrical construction is slightly more complex, it eliminates human error on the part of the operator. With the electrical design, the proper electrical contacts are made whenever the test figure is positioned. With the nonelectrical design, the operator must first position the test figure, and then set the indicator arm of the master indicator to correspond with it.

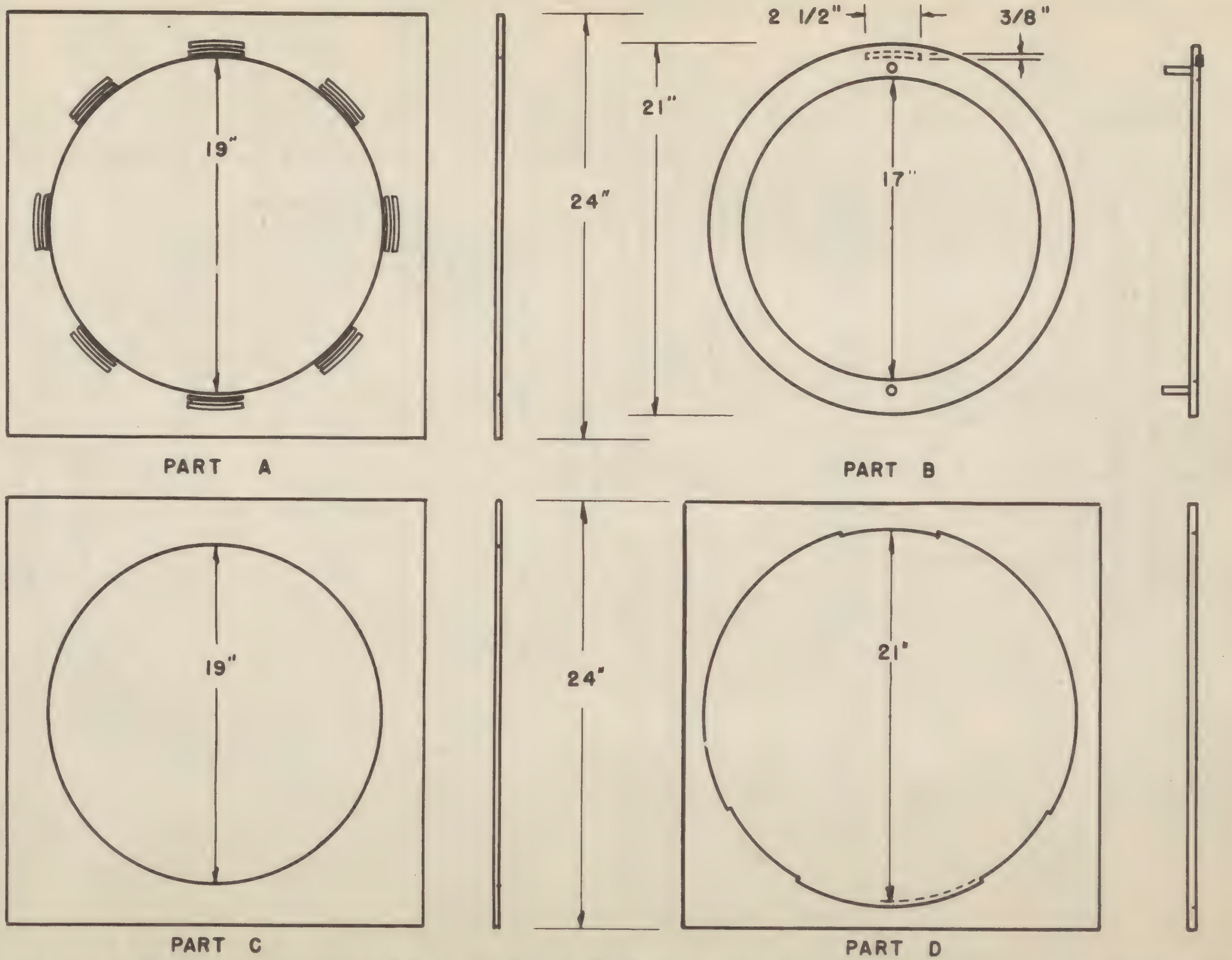
b. The rotating head is built up of three square pieces of plywood or masonite with circular holes in the center. The hole in the center piece has a larger diameter than that in the other two pieces, so that a circular channel is formed when the three pieces are assembled. The ring which holds the test figure rotates in this channel.

c. The electrical connections in the rotating head can be made from any available metal. Shim stock, approximately .015" thick, is excellent for this purpose and is available to the Battalion Motor Shops. The rubbing contact on the rotating ring can also be made from shim stock. A very good contact for this ring can also be made from the plunger type of friction catch such as is used in kitchen cabinets. This provides a spring-loaded contact which assures positive connection.

d. If a jig saw or hand saw is not available for sawing the circular sections, satisfactory results can be obtained with a simple hand-made saw. One end of an ordinary board about 1/2" by 1" is rounded slightly. To this rounded end, a short piece (approximately 1-1/2") of a hacksaw blade is nailed so that it projects 1/4" to 3/8" below the bottom edge of the board. This board with the



DRG NVT - 203 ASSEMBLY OF ROTATING HEAD SCALE 1=5



DRG NVT—204 PARTS OF ROTATING HEAD SCALE 1=8

hacksaw blade attached is nailed to the material to be cut out. When the board is rotated, a true circle will be cut in the material.

5. INDIVIDUAL AND MASTER INDICATORS. (Dwg. NVT - 205 and NVT - 206).--

a. These units are used by the examinees to indicate the position of the test figure.

b. The eight outer contacts correspond to the eight possible positions in which the test figure can be placed; they are connected directly to the corresponding contact on the rotating head and are held in place by screws or tacks. They can be made of shim stock or other metal.

c. Electrical contact between the outer contacts and the center disc is made by a strip of metal (shim stock) under the indicator arm. This arm is held in place by a machine screw which is passed through the center disc. The arm, which rotates about the screw, is spring-loaded to insure positive contact between the two points.

d. A substitute metal for these contacts can be obtained from No. 10 cans, which are available in every mess section.

6. ADJUSTMENTS NECESSARY FOR TESTING GROUPS OF VARIOUS SIZES.

a. The test figures employed (airplane and Landolt Ring) are designed to subtend a 2° visual angle at a viewing distance of 20 feet. The maximum dimension of the figures to subtend this 2° visual angle is 8-1/2 inches.

b. At a viewing distance of twenty feet, as many as eight men can be tested at one time. If the test quarters can be arranged to accommodate eight men, additional individual indicators will have to be constructed, and the BD-72 (12-drop) switchboard must be used instead of the BD-71 (6-drop) switchboard.

c. For smaller quarters, the test figure must be reduced in size in order to maintain the 2° visual angle. The reduction must be in accordance with the test distance, i.e., the test figure will be 25 percent smaller for a distance of 15 feet, and 50 percent smaller for a distance of 10 feet. The maximum number of men that can be tested at 15 feet is six; at 10 feet, four. No change need be made in the viewer.

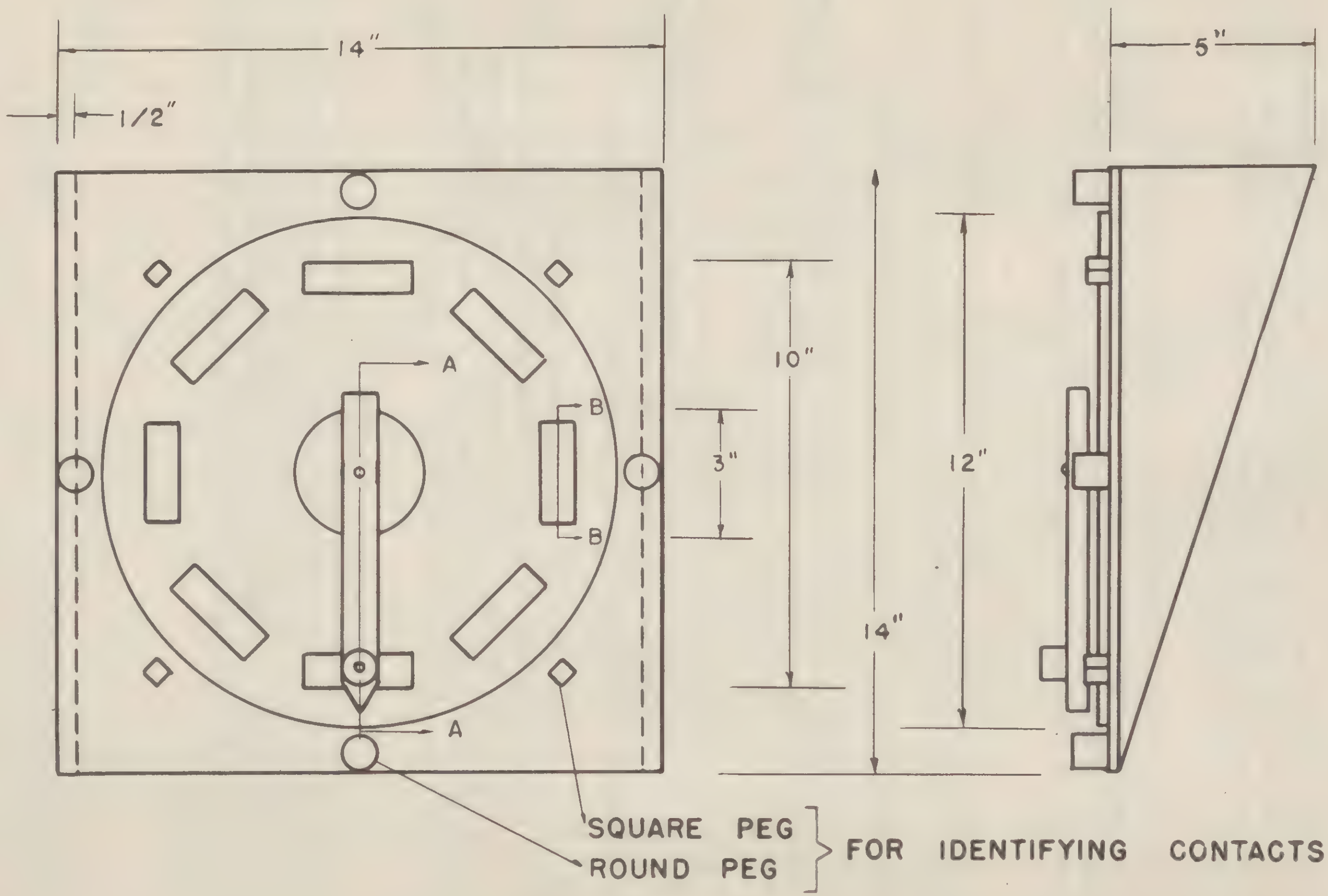
d. If very large quarters are available, twelve men can be tested at a viewing distance of 30 feet. For this distance, the viewer and the test figure must be enlarged 1-1/2 times. The light bulbs must be burned at 5 volts, and the sizes of the holes for the six levels of illumination are 5/16", 1/4", 3/16", 1/8", 3/32", and 1/16". Twelve individual indicators and the BD-72 switchboard are required for this test.

Part II

1. MASS TESTING SIGNALING SYSTEM.

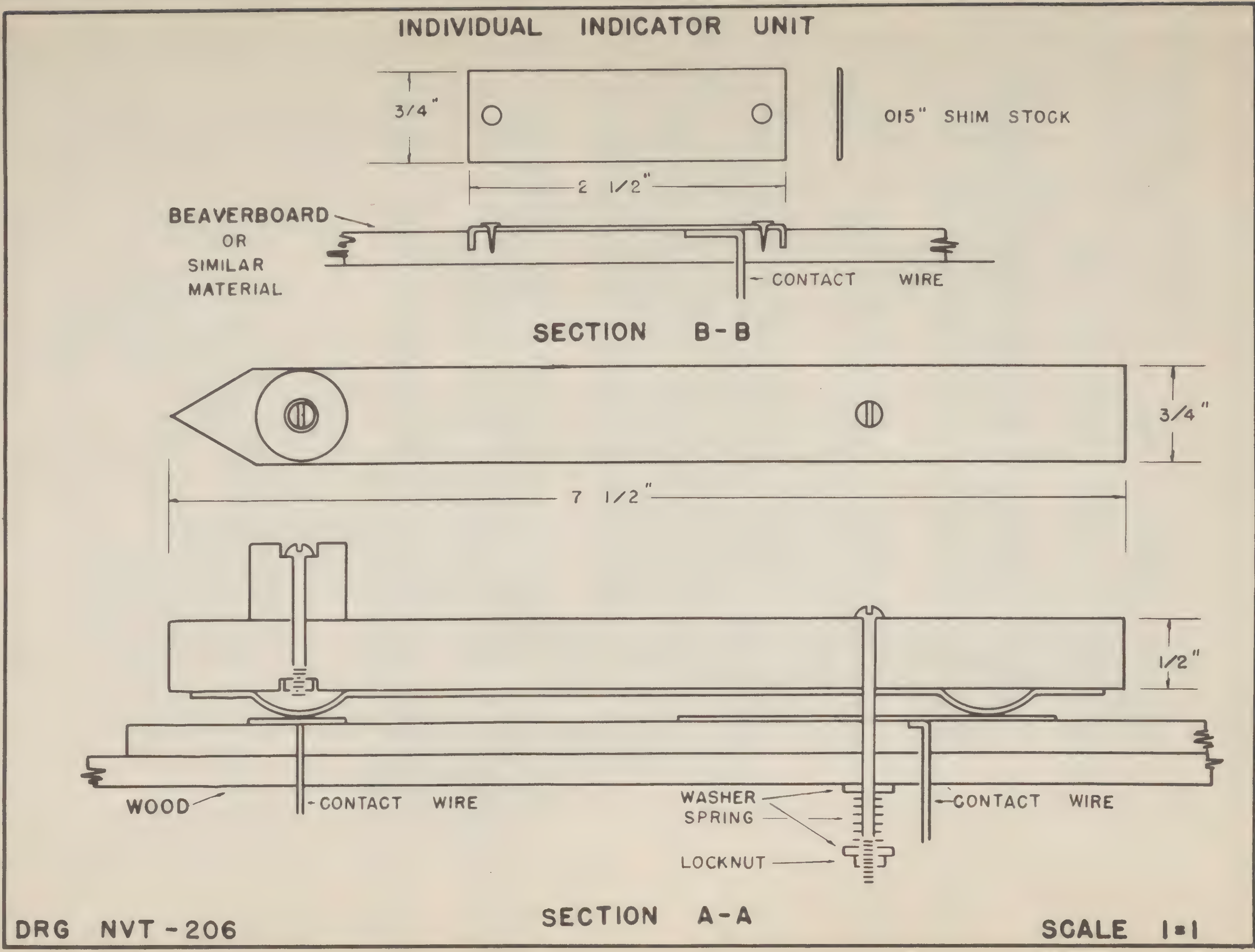
a. The signaling system consists of the rotating head (or master indicator), the individual indicators, a BD-71 or BD-72 switchboard, and sufficient W-130 or W-110 wire to make the proper connections.

INDIVIDUAL INDICATOR UNIT



DRG NVT - 205

SCALE 1 = 4



INDIVIDUAL INDICATOR UNIT
3/4"
2 1/2"
015" SHIM STOCK
BEAVERBOARD
OR
SIMILAR
MATERIAL
CONTACT WIRE
SECTION B-B
3/4"
7 1/2"
1/2"
WOOD
CONTACT WIRE
WASHER
SPRING
LOCKNUT
CONTACT WIRE
SECTION A-A
DRG NVT-206
SCALE 1=1

b. Wiring of the units is accomplished as follows: (Dwg. NVT - 207.)

(1) The inner ring of contacts of the rotating head are all connected to the "A" terminal of the multiple terminal strip (back compartment of the switchboard). Each contact of the outer ring is connected to the corresponding contact of each individual indicator, i.e., north contact on rotating head to north contact of each individual indicator, east to east, etc.

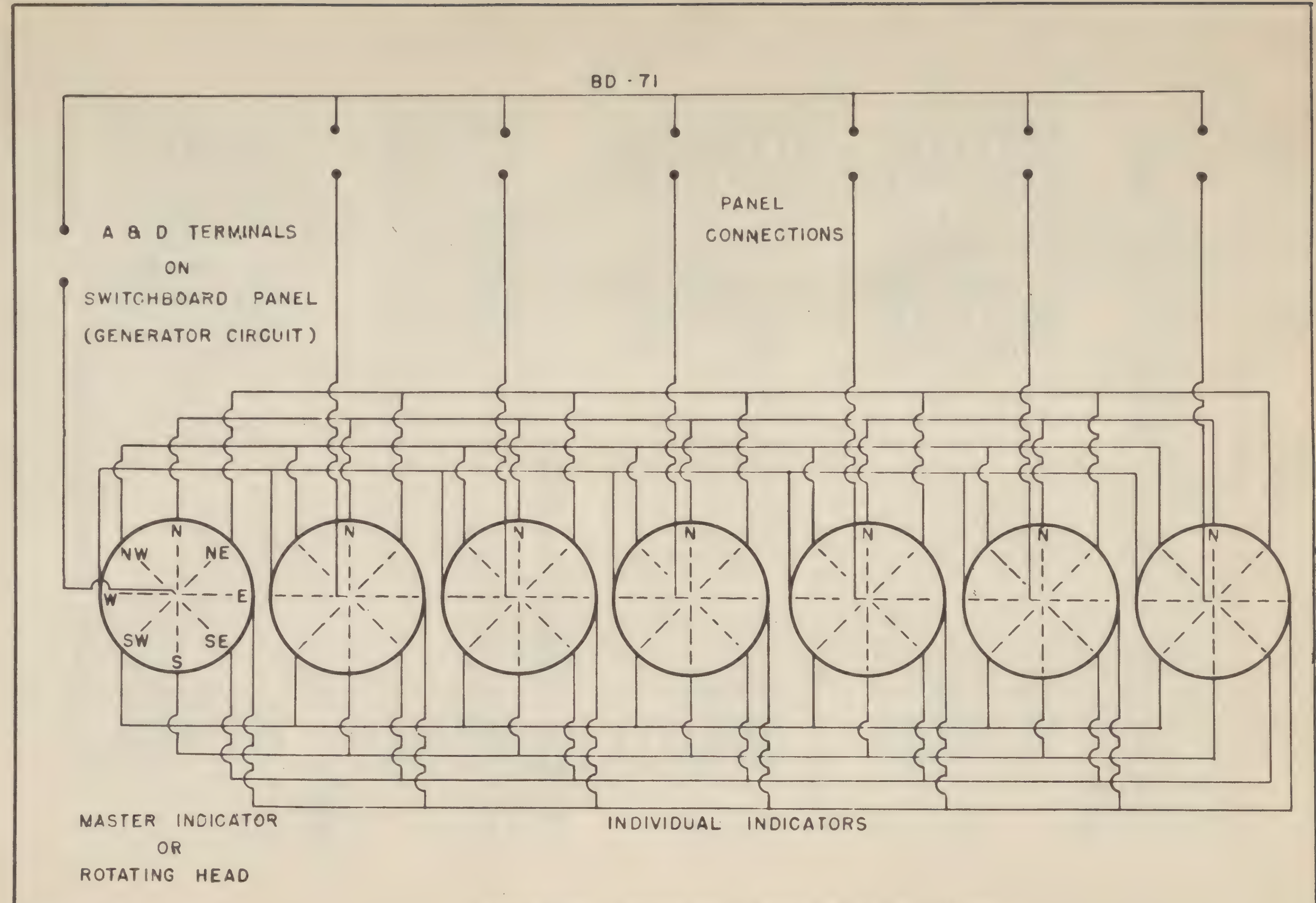
(2) From the center contact (metal disc) of each individual indicator, a wire is taken directly to the switchboard panel (top compartment) and attached to the corresponding binding post of the inner row. The outer row of binding posts (top compartment) are connected to the "D" terminal (multiple terminal strip in back compartment).

(3) The indicators should be wired to the switchboard so that Indicator No. 1 is connected to Panel No. 1 (left-hand panel), etc. This makes scoring easier.

(4) The "A" and "D" terminals of the multiple terminal strip connect the generator circuit of the switchboard to the rest of the circuit in series so that, when the figure is placed in the north position, for example, and the generator crank of the switchboard is turned, the panel drop of every examinee who has his individual indicator arm in the north position will fall. No circuit is completed if the indicator arm is in any position other than that of the test figure, and, consequently, the panel drop will not fall unless the examinee has indicated the correct position of the figure.

c. If a nonelectrical type of rotating head is used, another individual indicator called a master indicator must be employed. This is wired to the individual indicators in the same manner as the rotating head and must be positioned by the operator to correspond to the position of the test figure.

d. This signaling system is designed for use with any of the viewers developed, such as NVT, NVX, NVT-R, and NVT-FS. It may, of course, be used with other similar night vision testing apparatus.



WIRING SYSTEM FOR FAS NVT

APPENDIX III

TABLE OF ILLUMINATIONS

The following levels of illuminations were measured by the Taylor Low Brightness Meter. All readings are in foot-lamberts.

NVX 1

Level 1	0.0030	foot-lambert
Level 2	0.0017	foot-lambert
Level 3	0.00095	foot-lambert
Level 4	0.00049	foot-lambert
Level 5	0.00031	foot-lambert
Level 6	0.00017	foot-lambert
Level 7	0.00010	foot-lambert
Level 8	0.00005	foot-lambert

NVX 2, 3, 4, 5, 6, 7, 8, 10

Level 1	0.00030	foot-lambert
Level 2	0.00019	foot-lambert
Level 3	0.00011	foot-lambert
Level 4	0.000057	foot-lambert
Level 5	0.000030	foot-lambert
Level 6	0.000018	foot-lambert
Level 7	0.000010	foot-lambert
Level 8	0.000005	foot-lambert

NVX 13 (Also Pad-and-Pencil Test)

Level 1	0.00011	foot-lambert
Level 2	0.000057	foot-lambert
Level 3	0.000030	foot-lambert
Level 4	0.000018	foot-lambert
Level 5	0.000010	foot-lambert
Level 6	0.000005	foot-lambert

NVX 16

Level 1	0.000095	foot-lambert
Level 2	0.000050	foot-lambert
Level 3	0.000032	foot-lambert
Level 4	0.000018	foot-lambert
Level 5	0.000009	foot-lambert
Level 6	0.000005	foot-lambert
Level 7	0.000003*	foot-lambert
Level 8	0.000002*	foot-lambert

*Approximate - Below Range of Meter

NVT 14

Level 1	0.00030 foot-lambert
Level 2	0.00019 foot-lambert
Level 3	0.00011 foot-lambert
Level 4	0.000057 foot-lambert
Level 5	0.000030 foot-lambert
Level 6	0.000018 foot-lambert
Level 7	0.000010 foot-lambert
Level 8	0.000005 foot-lambert

NVT 15

Level 1	0.00017 foot-lambert
Level 2	0.000085 foot-lambert
Level 3	0.000028 foot-lambert
Level 4	0.000014 foot-lambert
Level 5	0.000005 foot-lambert

NVT PB

Level 1	0.00014 foot-lambert
Level 2	0.000083 foot-lambert
Level 3	0.000026 foot-lambert
Level 4	0.000015 foot-lambert
Level 5	0.000005 foot-lambert

NVT FS

Level 1	0.00018 foot-lambert
Level 2	0.000083 foot-lambert
Level 3	0.000027 foot-lambert
Level 4	0.000016 foot-lambert
Level 5	0.000010 foot-lambert

TC 44 I* - 10 September, 20 September, 21 September 1943

Sky	0.0040 foot-lambert
Background	0.000018 foot-lambert
Target	0.000065 foot-lambert

*Moon was nearly full. The test was given in thick woods.

TC 44 II and Z* - 21 October 1943

Sky	0.00018 foot-lambert
Ground	0.000022 foot-lambert

*This test was given on an ideal night.

OBSERVATION TEST I*

Sky	0.00013 foot-lambert
Ground (in open)	0.000015 foot-lambert

*Illumination was occasionally varied on this night by lightning flashes and dust raised by winds.

OBSERVATION TEST II*(trial run) - 4 November 1943

Sky 0.0005 to 0.001 foot-lambert

	Time	Brightness
Target and background	2030	0.0004 foot-lambert
	2100	0.00018 foot-lambert
	2145	0.00009 foot-lambert
	2320	0.00005 foot-lambert

*Moon was half-full and shifted in and out of cloud formations.

OBSERVATION TEST II*- (Given to Experimental Group) - 18 November 1943

Sky	0.00014 foot-lambert
Tree Background	0.000012 foot-lambert
Grass	0.000018 foot-lambert
Targets	0.000012 foot-lambert

*An ideal night.

OBSERVATION TEST II B - (285th FA Bn) - 23 November 1943

During the first part of the testing the floodlights were on at a ball park about a mile and a half away.

Sky	0.00022 foot-lambert
Grass	0.00007 foot-lambert
Background	0.000022 foot-lambert
2-1/2 ton truck	0.000022 foot-lambert
Command Car	0.000022 foot-lambert
Dirt Road	0.000032 foot-lambert
155-mm Howitzer	0.000020 foot-lambert
Trees	0.000014 foot-lambert

Readings after park lights went off. Time 2130

2-1/2 ton truck	0.000012 foot-lambert
Command Car	0.000012 foot-lambert
155-mm Howitzer	0.000012 foot-lambert
Dirt Road	0.000018 foot-lambert

APPENDIX IV

DETAILS OF FIELD ARTILLERY SCHOOL MASS NIGHT VISION TESTER, MODEL NVT-R2

1. VIEWER (Dwgs. NVT-R2 301 and 302).--

a. The viewer for this model is a rectangular box 20" x 20" x 14". At the back of the viewer is a radium-activated plaque holder assembly (A). This assembly has a vertical slide or shutter (B), which, when closed, prevents any outside lights from superactivating the radium light source. The horizontal channels in front of the vertical shutter provide a means by which slides (C) can be inserted so that only a part of the radium-activated light source is exposed to the viewing screen. By varying the size of the area exposed to the screen, the various light levels are obtained.

b. The open front end of the viewer is covered with a viewing screen of standard white tracing cloth.

2. LIGHT SOURCE AND LIGHT INTENSITIES.--

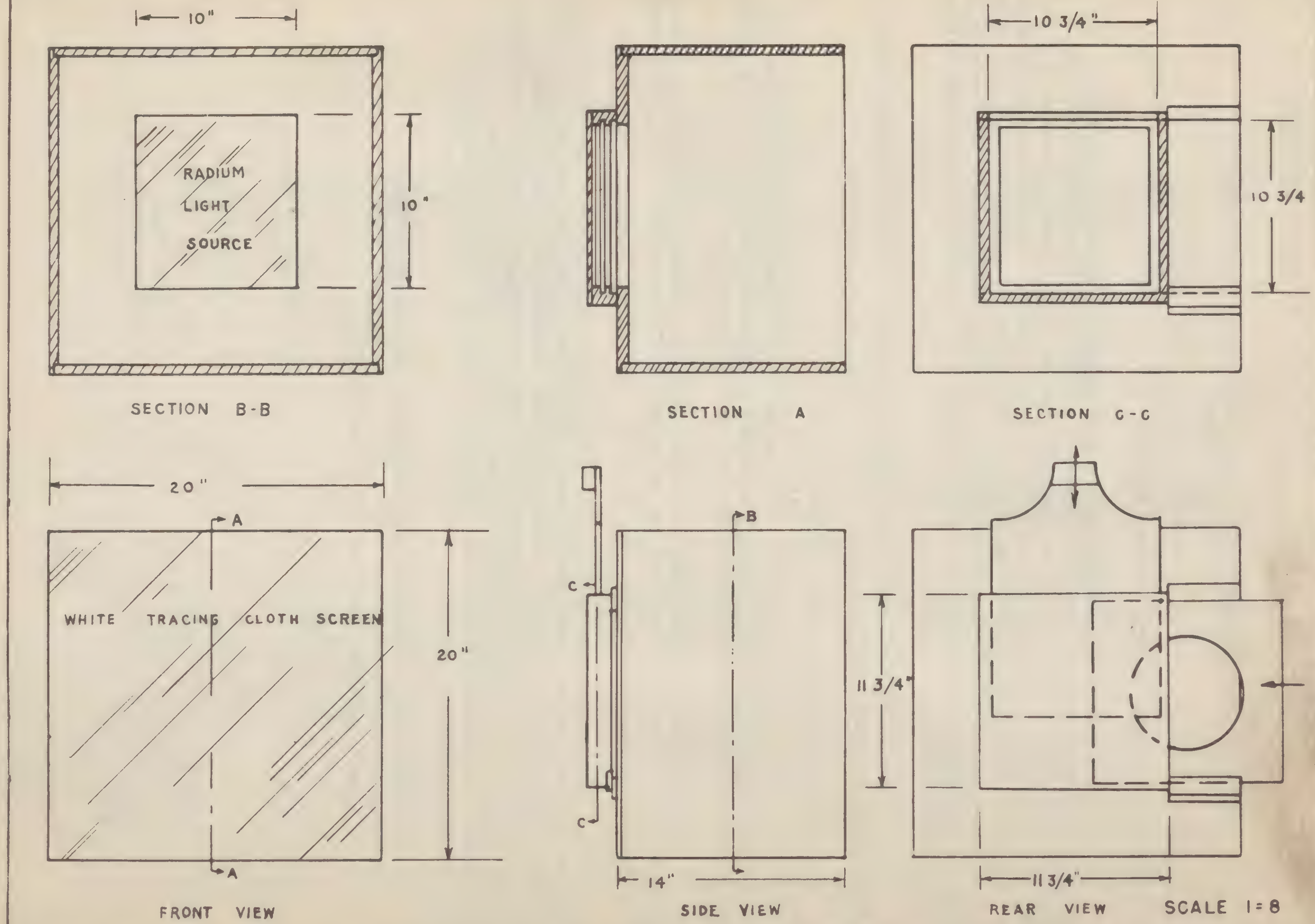
a. The source of light for this model is a radium-activated plaque with 100 square inches of surface. This plaque was prepared especially for this tester by the United States Radium Corporation, 535 Pearl Street, New York, New York.

b. The plaque is mounted 15 inches from the viewing screen. The desired levels of light intensity are obtained by means of slides in which holes of graded size have been drilled (see Dwg. NVT-Ra 302).

c. The composition of this plaque is so uniform that the light levels obtained on the viewing screen are directly proportional to the area of the plaque exposed. Thus, if the intensity obtained by the exposure of a certain area is known, it is easy to calculate the area that must be exposed to obtain any other desired level. For example, if 100 square inches of exposed area gives 0.00020 foot-lambert on the viewing screen, 50 square inches of exposed area will give 0.00010 foot-lambert.

3. ROTATING HEAD, INDIVIDUAL INDICATORS AND SIGNALING SYSTEM.--

a. See specifications for NVT (Appendix II).



DRG NVT-R2-301 NVT RADIUM VIEWER LESS ROTATING HEAD & TEST FIGURE

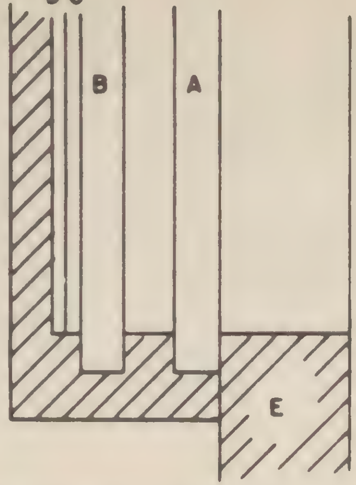
A - CHANNEL FOR HORIZONTAL SLIDES

B - CHANNEL FOR VERTICAL SLIDE

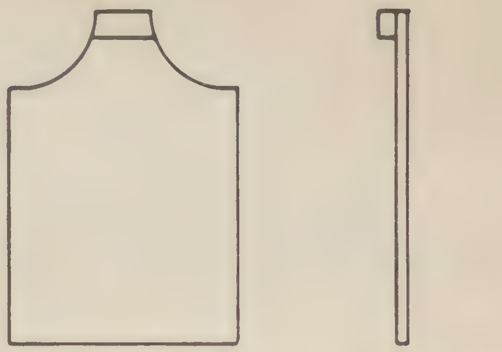
C - GLASS

D - RADIUM PLAQUE LIGHT SOURCE

E - WOOD BOX

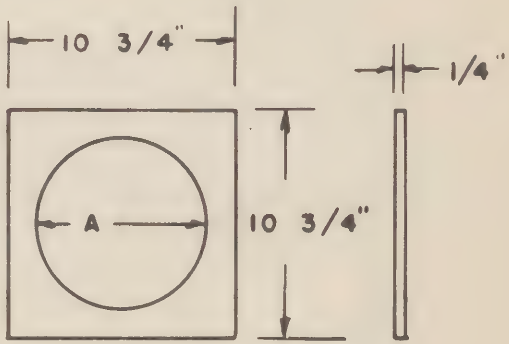


PORTION OF SECTION A-A
SCALE 1=1



VERTICAL SLIDE TO COVER LIGHT SOURCE

LEVEL	DIAMETER OF HOLE "A"
1	7 3/4"
2	5 3/4
3	4 3/8
4	3 3/8
5	2 1/2
6	1 3/4



HORIZONTAL SLIDE TO GIVE LEVELS OF ILLUMINATION

DRG NVT-R2-302

DETAILS - RADIUM BOX

SCALE 1=8

Arnold